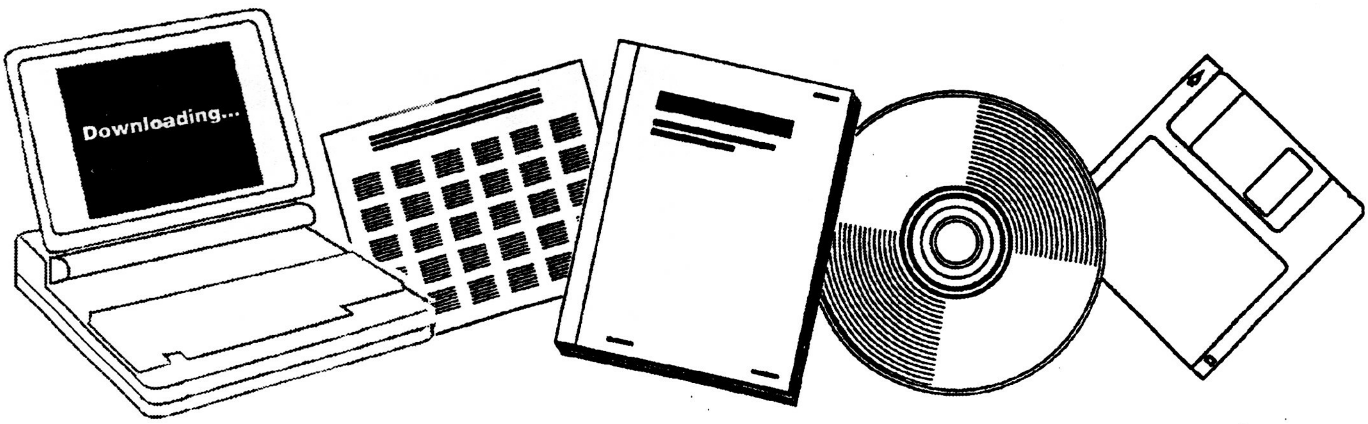
DESIGN AND FABRICATION OF THE BRAYTON CYCLE HIGH PERFORMANCE COMPRESSOR RESEARCH PACKAGE FINAL REPORT

AIRESEARCH MFG. CO., PHOENIX, ARIZ

29 NOV 1967



NASA CR-72533
APS-5269-R

FINAL REPORT
DESIGN AND FABRICATION OF THE BRAYTON CYCLE HIGH PERFORMANCE COMPRESSOR RESEARCH PACKAGE

Prepared for

National Aeronautics and Space Administration

by

AiResearch Manufacturing Company of Arizona

November 29, 1967

Contract NAS3-9427

Technical Management

NASA Lewis Research Center
Cleveland, Ohio

Space Power Systems Division
James H. Dunn

ABSTRACT

AiResearch Manufacturing Company of Arizona designed, fabricated, performed acceptance testing and delivered to the NASA a Brayton-Cycle Compressor Research Package under NASA Contract NAS3-9427.

The research package is aerodynamically identical to the compressor used in the NASA Brayton Rotating Units (BRU) to be delivered under the same contract. This compressor research package will be utilized at the NASA Lewis Research Center for complete component performance evaluation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FINAL REPORT
DESIGN AND FABRICATION OF THE BRAYTON CYCLE HIGH PERFORMANCE COMPRESSOR RESEARCH PACKAGE

1.0 INTRODUCTION

This report submitted by the AiResearch Manufacturing Company of Arizona, a division of the Garrett Corporation, describes the design, fabrication, inspection and acceptance testing of the NASA Brayton-Cycle Compressor Research Package.

The research package consists of a 4.25-inch diameter compressor wheel and shaft mounted on ball bearings and the associated mounting hardware. The aerodynamic passages of the impeller and diffuser are identical to the compressor of the Brayton Rotating Units (BRU) to be delivered under the same contract.

The Compressor Research Package underwent a mechanical integrity spin-up test as reported in the acceptance test section of this report. Subsequently, the research package was shipped to the NASA-Lewis Research Center in accordance with the contract requirements.

2.0 DETERMINATION OF DESIGN CONDITIONS

During the preliminary design phase of the BRU Program, system studies were performed to determine trends toward establishing the optimum BRU configuration and its corresponding design points at three representative power levels-- 2.25 kw_e, 6.0 kw_e, and 10.5 kw_e net electrical output. Extensive parametric analysis evolved a system design which yielded high cycle efficiency and conditions favorable to the BRU throughout the 2.25 kw_e to 10.5 kw_e power range.

The compressor design conditions resulting from that analysis at the reference design power level of 6.0 kw_e are as follows:

Working fluid	XeHe mixture, equivalent molecular weight = 83.8
Compressor inlet pressure (total)	13.5 psia
Compressor inlet temperature (total)	540°R
Compressor pressure ratio	1.9
Compressor mass flow rate	0.756 lb/sec.
Compressor rotating speed	36,000 rpm
Compressor specific speed	0.11

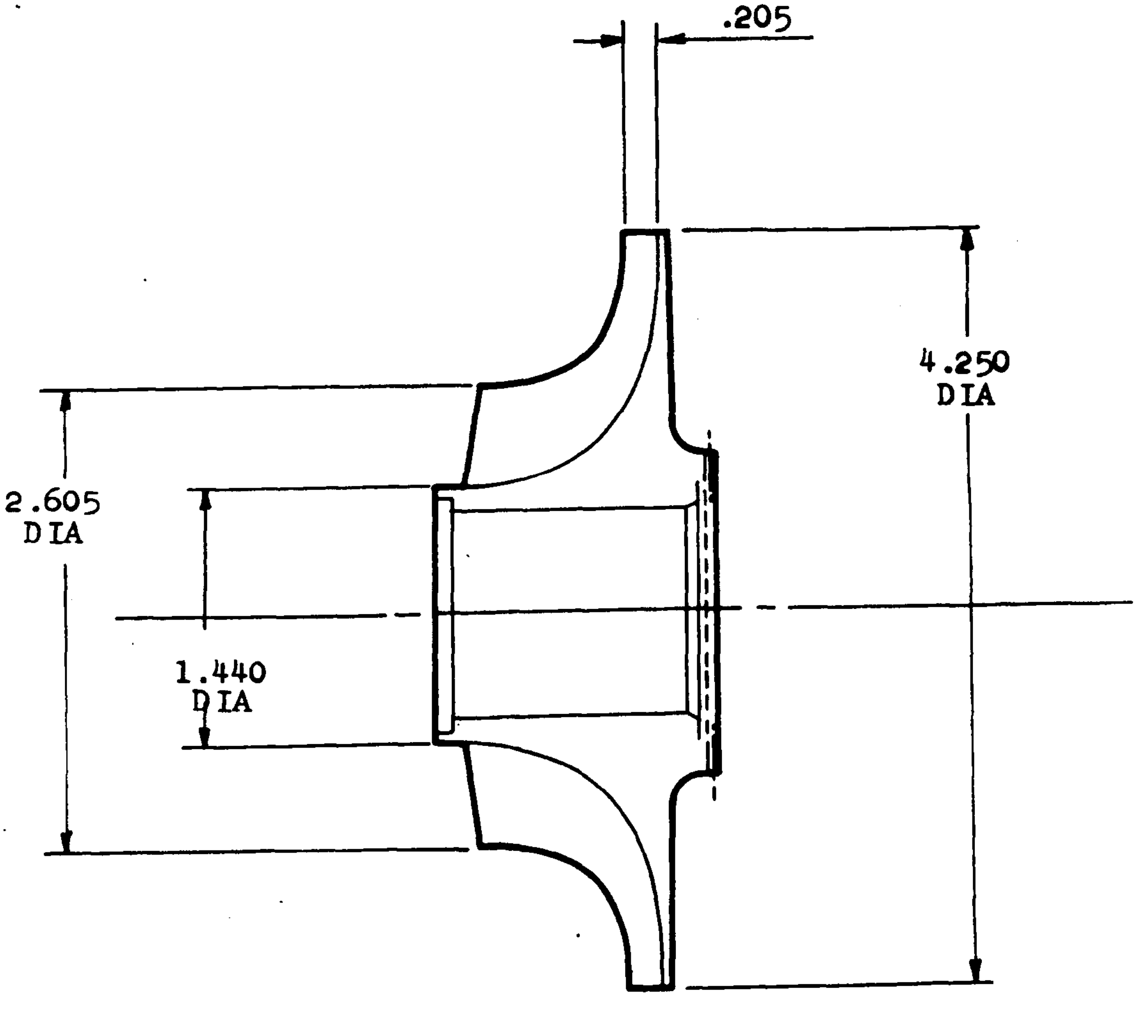
3.0 COMPRESSOR DESIGN

3.1 Aerodynamic Design Approach

After reviewing the compressor design conditions obtained from the system analysis, it was determined that an exact scale of an existing compressor stage would yield excellent efficiency. To assist in reaching this conclusion, the measured performance of the existing compressor was utilized, in a computer program to predict the performance in the XeHe mixture and appropriate corrections were made to account for expected efficiency changes. Similar past performance predictions based on air data for compressors to be operated in gases other than air have proven to be reliable.

The only new component required--the scroll--was designed to provide a minimum total pressure loss from the diffuser exit to the scroll exit using standard scroll design practice. In addition, only minor mechanical diffuser modification would be required. Further study indicated that based on the existing technology, it was not likely that a new compressor designed specifically for the BRU would exceed the expected efficiency of a scaled stage. Estimates of efficiency deterioration due to lower Reynold's number, smaller and less accurate parts, and higher relative axial clearance led to a predicted design efficiency of greater than 80 percent.

The final calculated scale factor was 0.514. The meridional dimensions of the scaled wheel are given in Figure 1.



BRU COMPRESSOR WHEEL

FIGURE 1

The compressor wheel from which the BRU has been scaled is typical of the latest generation of small centrifugal compressors which employ backward curved blading (the blade is not radial at the exit). Using advanced analysis techniques and sophisticated development procedures, this type of design has exhibited consistently high efficiencies over a wide range of pressure ratios.

3.2 Aerodynamic Design Data

The following is a tabulation of the aerodynamic design data, for the compressor.

(a) Velocity vector diagrams.
(See Figure 2 for impeller velocity diagrams and Figure 3 for diffuser and scroll velocity diagrams).

(b) Efficiencies
(See Table 1)

(c) Pressure ratios
Total-to-total pressure ratio = 1.900
Total-to-static pressure ratio = 1.981

(d) Actual specific work = 16.58 hp per lb per sec.

(e) Weight flow = 0.756 lb per sec.

(f) Stator and rotor physical dimensions
(See Figure 4)

(g) Total and static pressures at inlet and exit of stator and rotor (See Table 1)

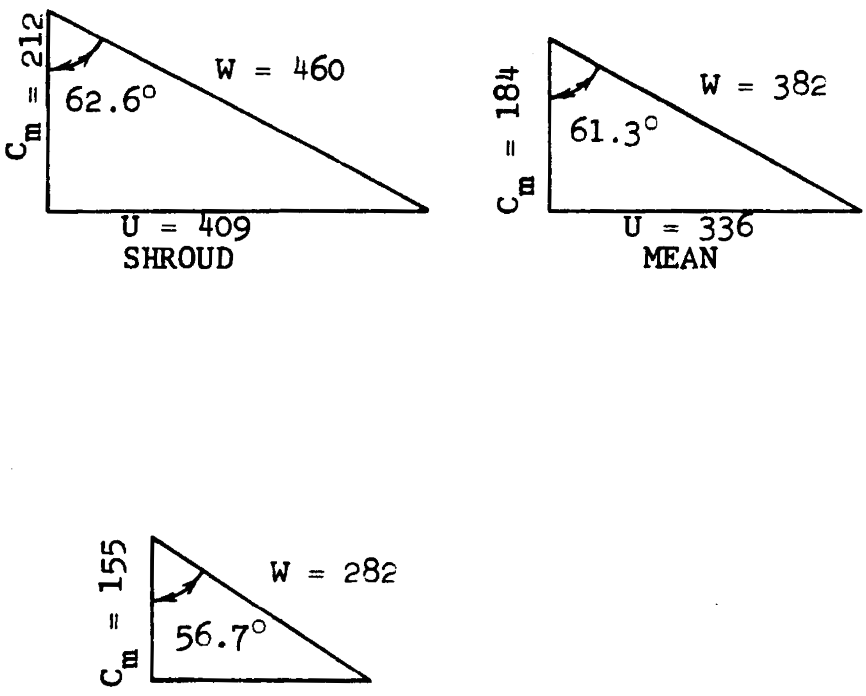
(h) Total temperatures at inlet and exit
(See Table 1)

(i) Specific speed = 0.111

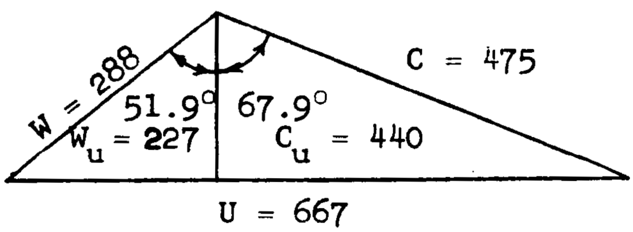
(j) Physical speed = 36,000 rpm

(k) Working fluid = XeHe mixture (molecular weight = 83.8)

(a) IMPELLER INLET VELOCITY TRIANGLES (INSIDE OF BLADE INCLUDING BLADE BLOCKAGE)



(b) IMPELLER EXIT VELOCITY TRIANGLES (MEAN VELOCITY INSIDE OF BLADE INCLUDING BLADE BLOCKAGE)

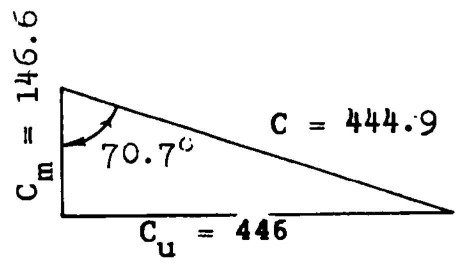


EXIT MEAN

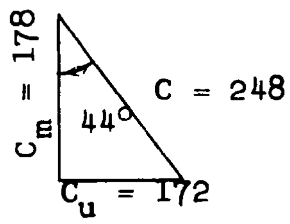
COMPRESSOR IMPELLER DIAGRAMS

FIGURE 2

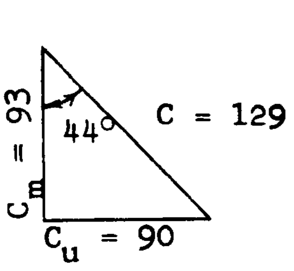
(a) DIFFUSER INLET (MEAN JUST UPSTREAM OF VANE)



(b) DIFFUSER EXIT (CORE VELOCITY INSIDE OF BLADE)



(c) SCROLL INLET (MEAN VELOCITY)

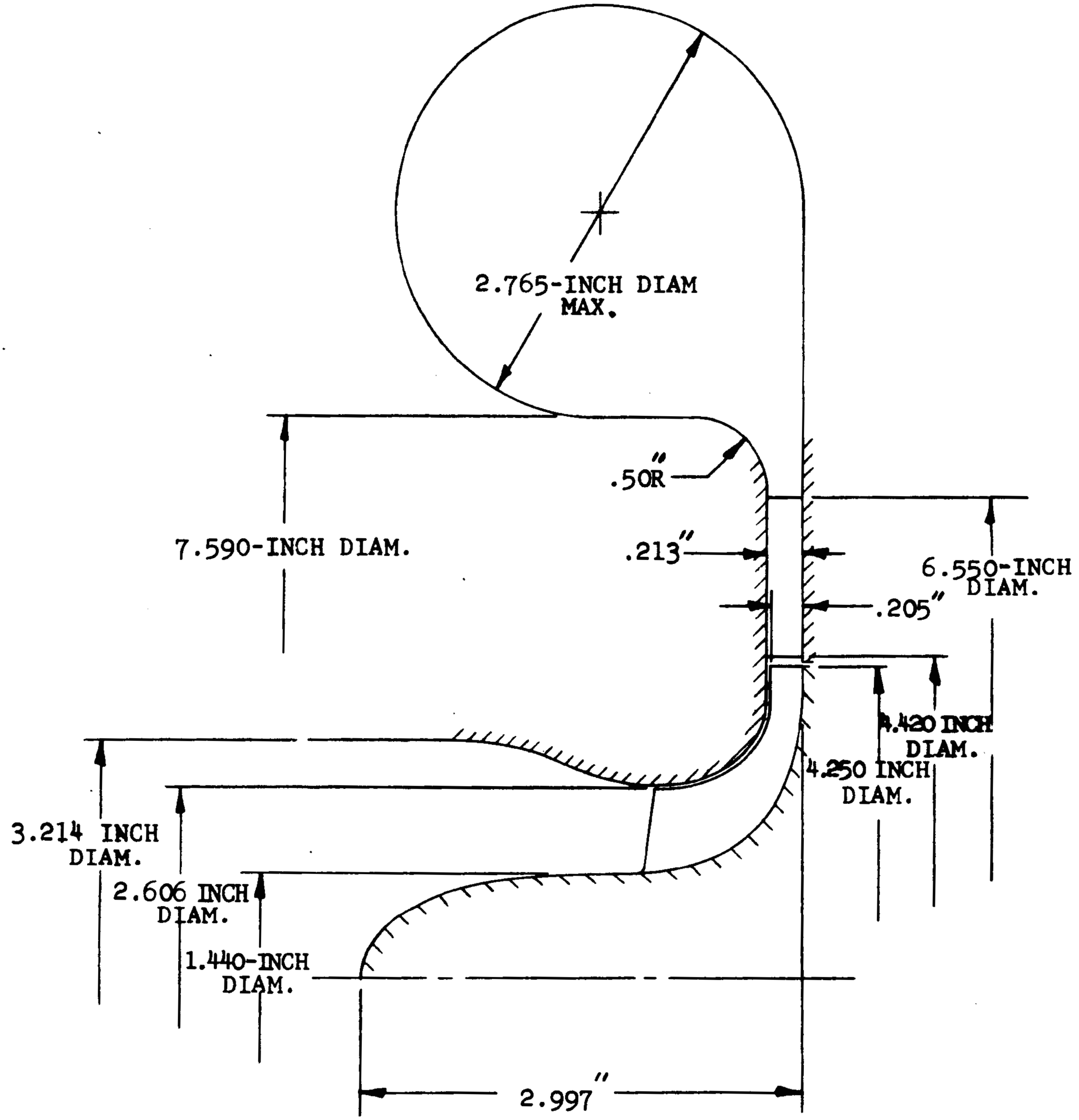


(d) SCROLL EXIT MEAN VELOCITY = 61 FT PER SEC.
YIELDING $M_{EXIT} = 0.071$

COMPRESSOR DIFFUSER AND SCROLL VELOCITY DIAGRAMS
FIGURE 3

TABLE I
PRESSURE, TEMPERATURE, AND EFFICIENCY
AT STATIONS THROUGH THE COMPRESSOR

	P_{Total} (psia)	P_{Static} (psia)	T_{Total} (°F)	Efficiency Up To Location
Inlet (Outside Blade)	13.50	12.94	540.0	--
Impeller exit (Mean)	27.40	20.89	737.6	89.5
Diffuser Inlet (Core)	27.25	21.60	737.6	88.7
Diffuser Exit (Core)	27.25	25.40	737.6	--
Scroll Inlet (Mean)	25.81	25.39	737.6	81.0
Scroll Exit (Mean)	25.65	25.57	737.6	80.0



NASA BRU COMPRESSOR
ROTOR AND STATOR PHYSICAL DIMENSIONS

FIGURE 4

3.3 Compressor Wheel Stress Analysis

The BRU impeller, as discussed in Section 3.1, is an exact 0.514 scale-down of an existing impeller used extensively in a turboprop engine. The full sized impeller operates at a design speed of 41,700 rpm. Material density and scale factors applied to experimentally-determined blade stresses in the full-size wheel show that the blade stress levels in the BRU impeller are approximately 35 percent of those existing in the full-size wheel. The blade stress factor was determined as follows:

Centrifugal stress $\propto$ (density) (radius)^2 (speed)^2

where: BRU wheel speed = 36,000 rpm
Full-size wheel speed = 41,700 rpm
BRU wheel material = 403 CRES (γ = 0.28 lb/in^3)
Full-size wheel material = titanium (δ = 0.16 lb/in^3)

Hence:

$$\text{Centrifugal blade stress for BRU impeller} = \left(\frac{.28}{.16}\right) (.514)^2 \left(\frac{36,000}{41,700}\right)^2$$

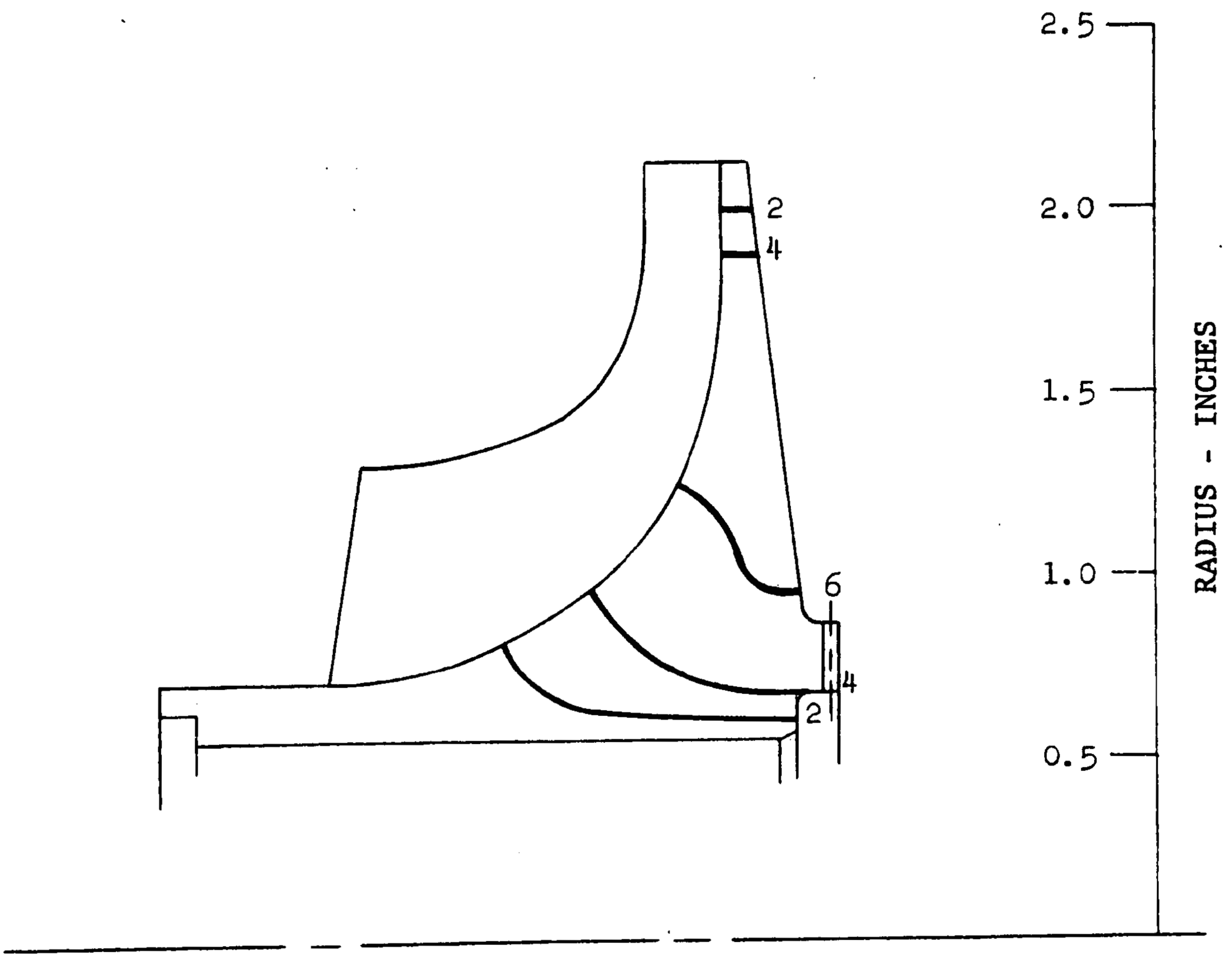
$$\approx 0.344 \times \text{Centrifugal blade stress for full-size impeller}$$

Applying this factor to the experimentally determined blade stress values for the full-size impeller results in maximum values for the BRU impeller of 25,000 psi.

A stress analysis was performed on the BRU impeller to determine the centrifugal stresses in the wheel disk at its operating speed

of 36,000 rpm. Figures 5 & 6 present, graphically, the radial and tangential stresses expected in the disk.

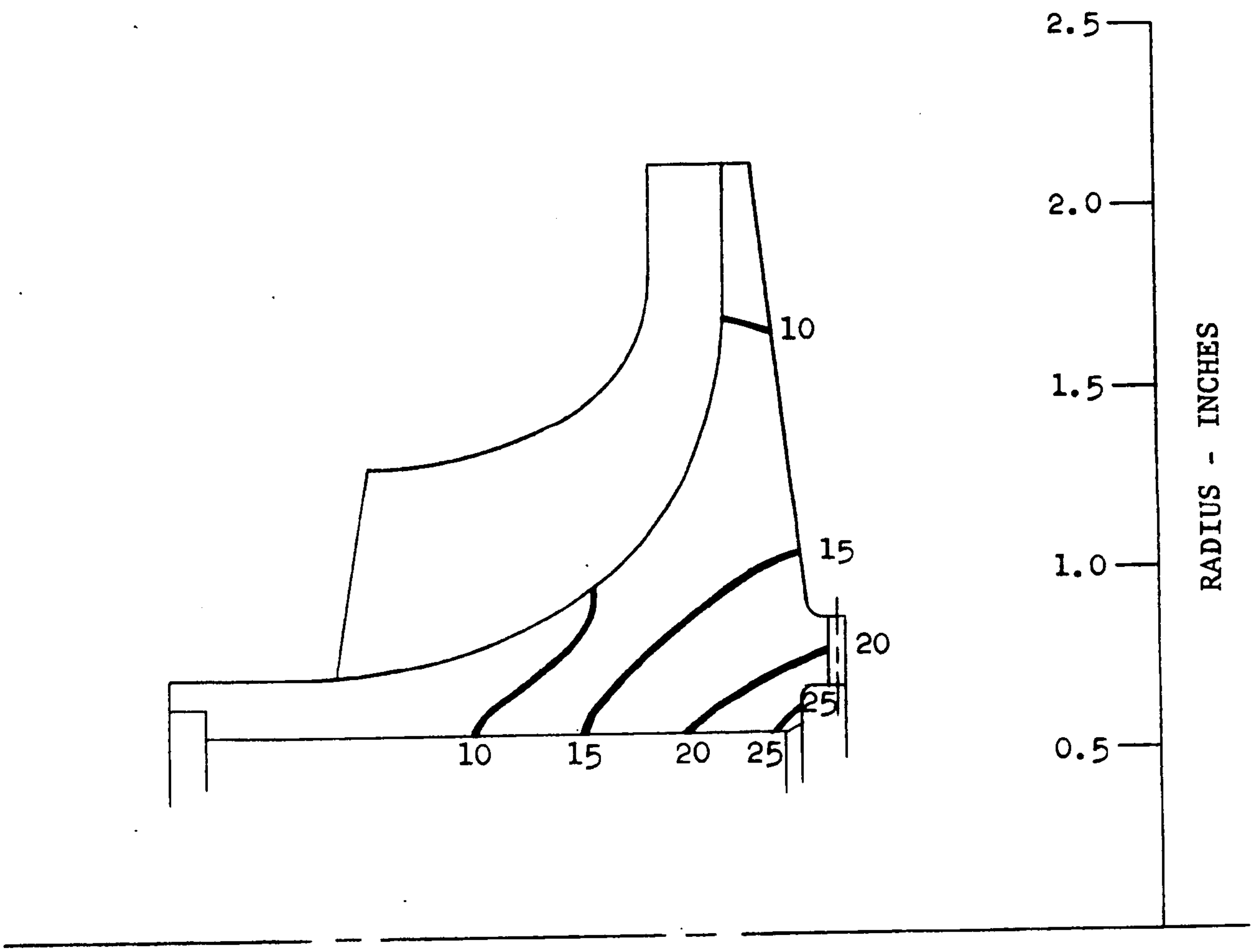
Yielding of the disk may be expected at a minimum speed of 65,000 rpm and the minimum burst speed may be expected at 95,000 rpm. Since creep of the 403 CRES wheel material is negligable at the temperatures and stress levels encountered in this application, the BRU compressor wheel may be considered essentially an infinite-life wheel.



NOTES:
1. OPERATING SPEED = 36,000 RPM
2. MATERIAL = 403 CRES
3. ALL STRESSES IN KSI

NASA BRU COMPRESSOR IMPELLER
RADIAL STRESS DISTRIBUTION

FIGURE 5



NOTES:
1. OPERATING SPEED = 36,000 RPM
2. MATERIAL = 403 CRES
3. ALL STRESSES IN KSI
4. AVERAGE TANGENTIAL STRESS = 12,750 PSI

NASA BRU COMPRESSOR IMPELLER
TANGENTIAL STRESS DISTRIBUTION

FIGURE 6

3.4 Critical-Speed Analysis

In order to perform a critical-speed analysis for the compressor research package, the operating speed range for performance testing had to be determined. The desired speed range for the package is set forth in Table 2 . Selection of the speed range was coordinated with the cognizant personnel at the NASA-Lewis Research Center.

The elastic and mass model of the rotating assemblies used in the critical-speed analysis is shown in Figure 7 As can be noted, the balanced flexible coupling was included in the elastic and mass model. In addition, the Contractor-selected drive turbine, that was used for the acceptance testing of the research package was included to determine whether or not the flexible coupling arrangement would significantly influence the rigid-body critical speeds of the research package. The critical speeds of the compressor package rotating assembly, plotted as a function of bearing resilient-mount spring rates, are shown in Figure 8 for the case of equal spring rate mounts at both bearings. Figure 8 shows that the use of 30,000 ppi resilient mounts at each bearing will allow the compressor research package to operate over the range of 25,550 to 66,165 rpm without encountering rigid-body critical speeds. The bending mode critical is shown to be approximately 74,000 rpm. It should be noted that the drive turbine system critical speed (first system critical) is very low and does not influence the critical speeds of the compressor package. Bearing loads for the anticipated operating range (25,550 to 66,165 rpm) are plotted as a function of speed in Figure 9 for an assumed rotor c.g. eccentricity of 0.0002 inch.

TABLE 2

COMPRESSOR RESEARCH PACKAGE OPERATING SPEED RANGE

Compressor:

Test Fluid	Percent Operating Speed 50	100
Argon (60°F inlet)	25,550 rpm	51,100 rpm
Air (60°F inlet)	30,075 rpm	60,150 rpm

Overspeed condition - 110 percent of 60,150 = 66,165 rpm
DESIGN SPEED RANGE = 25,500 - 66,165 rpm

NOTE: Testing with Helium-Xenon Gas Mixture is not a requirement.

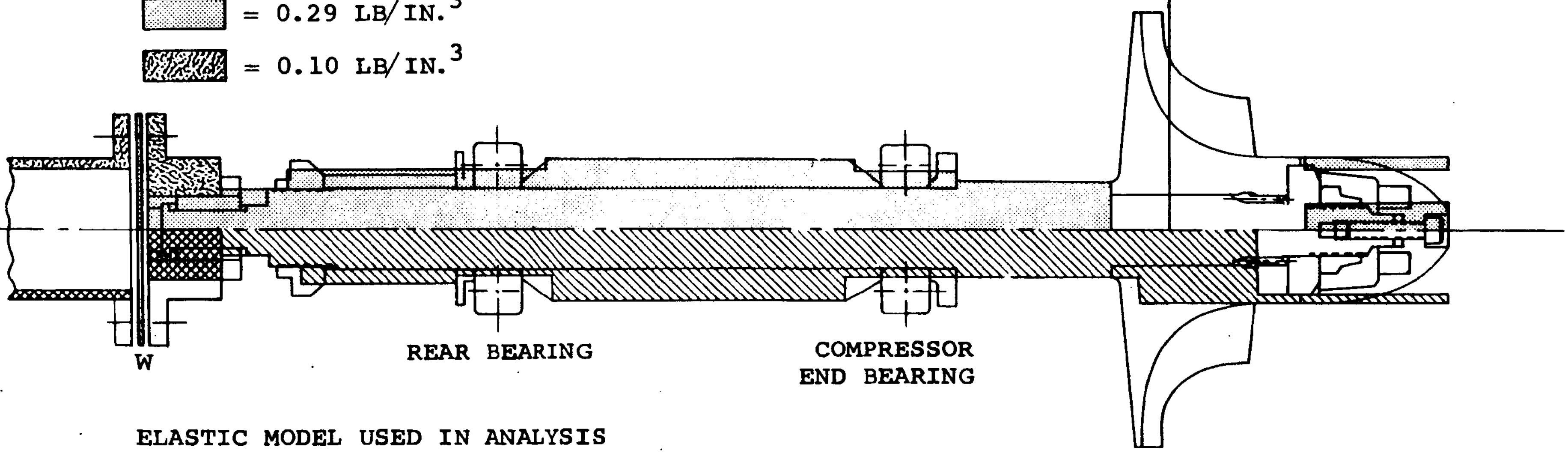
MASS MODEL USED IN ANALYSIS
IS AS SHOWN ABOVE CENTERLINE

DENSITY LEGEND

= 0.29 LB/IN.^{3}

= 0.10 LB/IN.^{3}

MASS LB SEC^2/IN.
I_P IN-LB-SEC^2
I_D IN-LB-SEC^2



ELASTIC MODEL USED IN ANALYSIS
IS AS SHOWN BELOW CENTERLINE

LEGEND OF MODULUS
OF ELASTICITIES

$E = 2.9(10)^7$ LB/IN.^{2}

$E = 1.0(10)^7$ LB/IN.^{2}

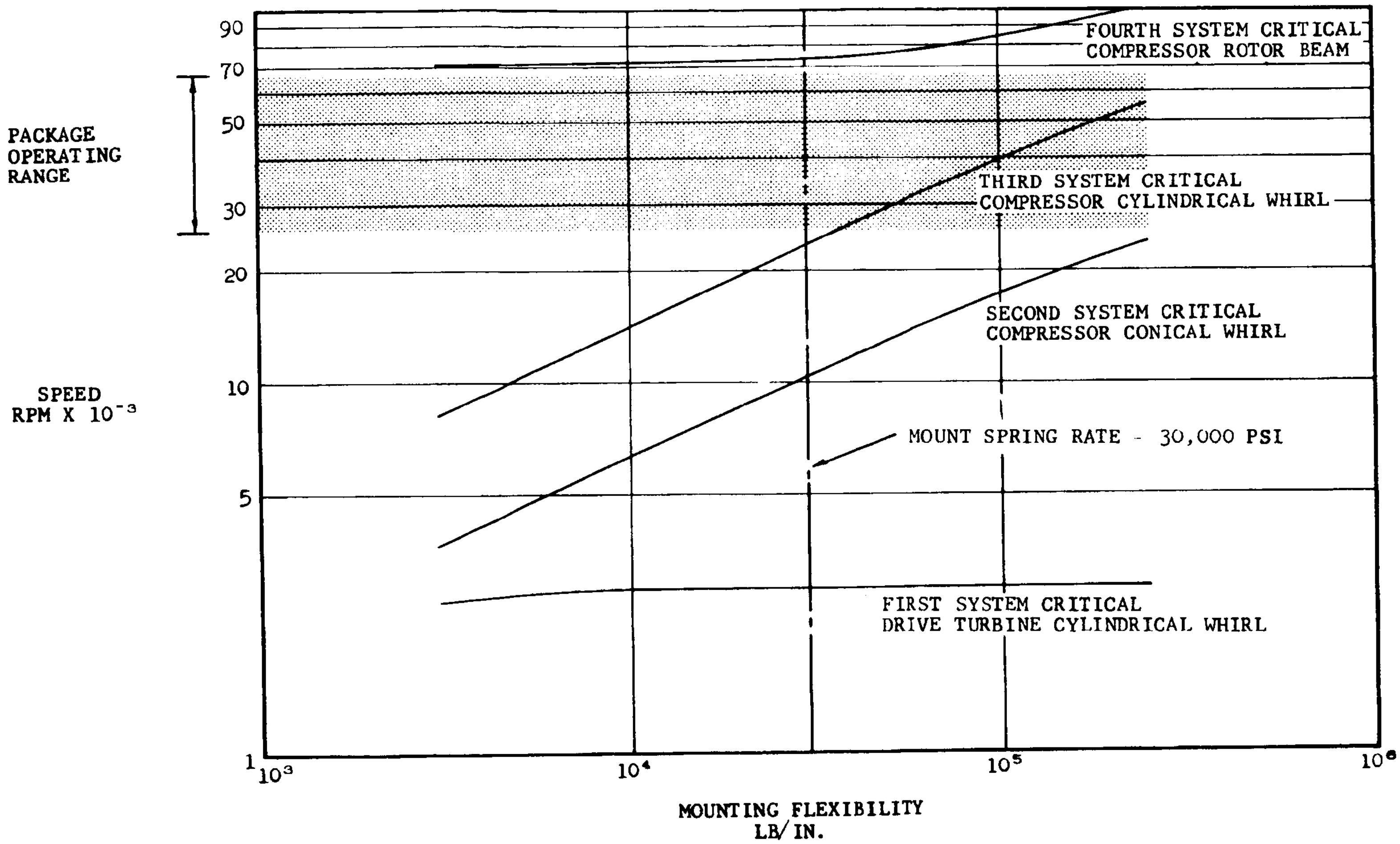
NOTES:

(1) DRIVE TURBINE MOUNTED ON FLEXIBLE MOUNTS WITH 1500 LB/IN. SPRING RATES.

(2) THE MOMENT TRANSMITTED THROUGH THE "WAFERS" WAS ASSUMED NEGLIGIBLE. IN ESSENCE, A PINNED-JOINT WAS ASSUMED AT EACH END OF THE FLEXIBLE COUPLING.

SYSTEM USED IN CRITICAL SPEED
BEARING LOAD ANALYSIS OF THE
BRU COMPRESSOR RESEARCH PACKAGE

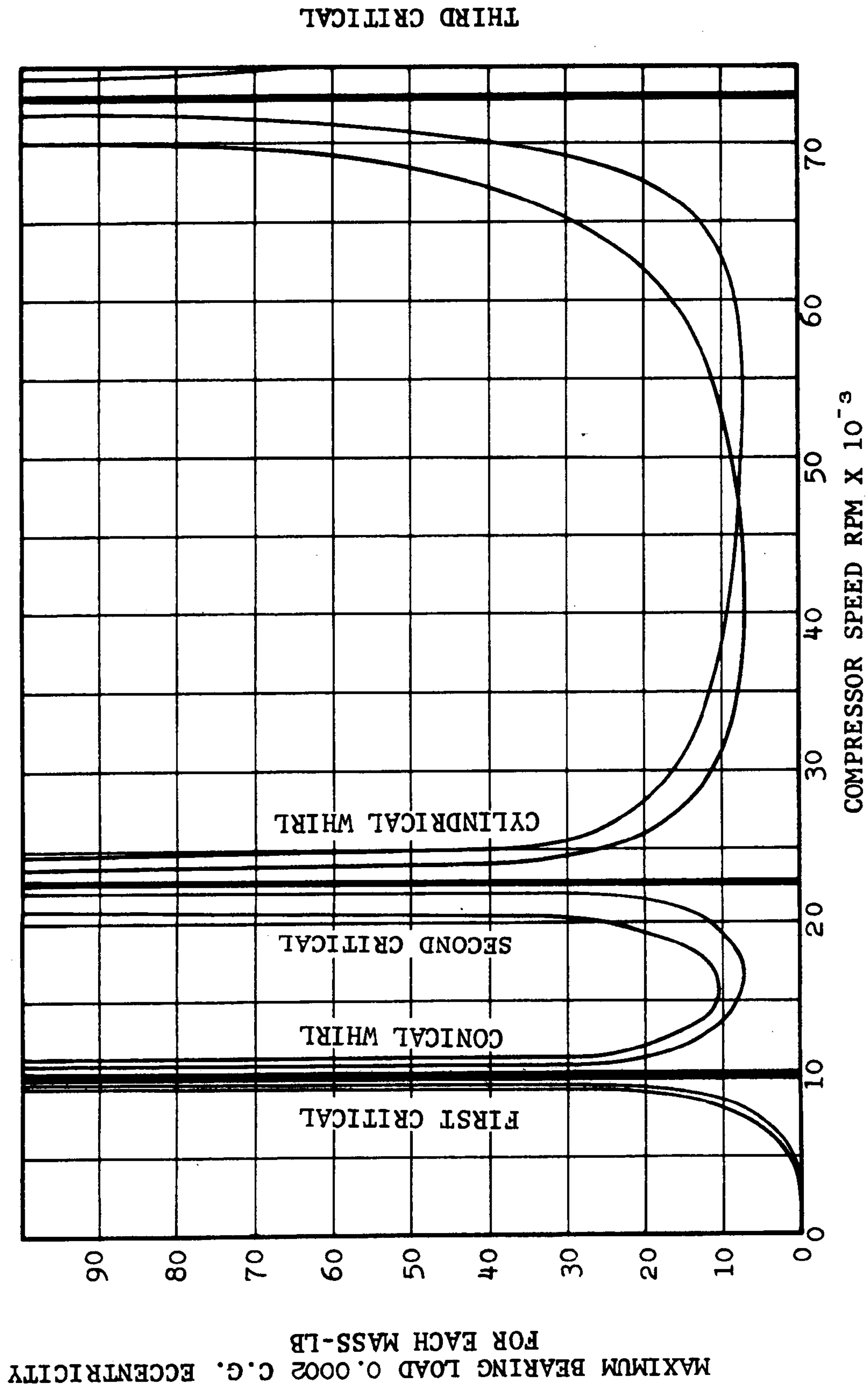
FIGURE 7



NOTES: (1) REF: FIGURE 7
(2) EQUAL MOUNTINGS ON COMPRESSOR ROTOR

BRU COMPRESSOR RESEARCH PACKAGE
CRITICAL SPEEDS AS A FUNCTION
OF MOUNTING FLEXIBILITY
FOR BOTH MOUNTS EQUAL

FIGURE 8



NOTES:
1. REF. FIGURE 8
2. BOTH BEARINGS FLEXIBLY MOUNTED
$K = 3\ (10)^4$ LB/PER INCH

BEARING LOADS FOR BRU
COMPRESSOR RESEARCH PACKAGE

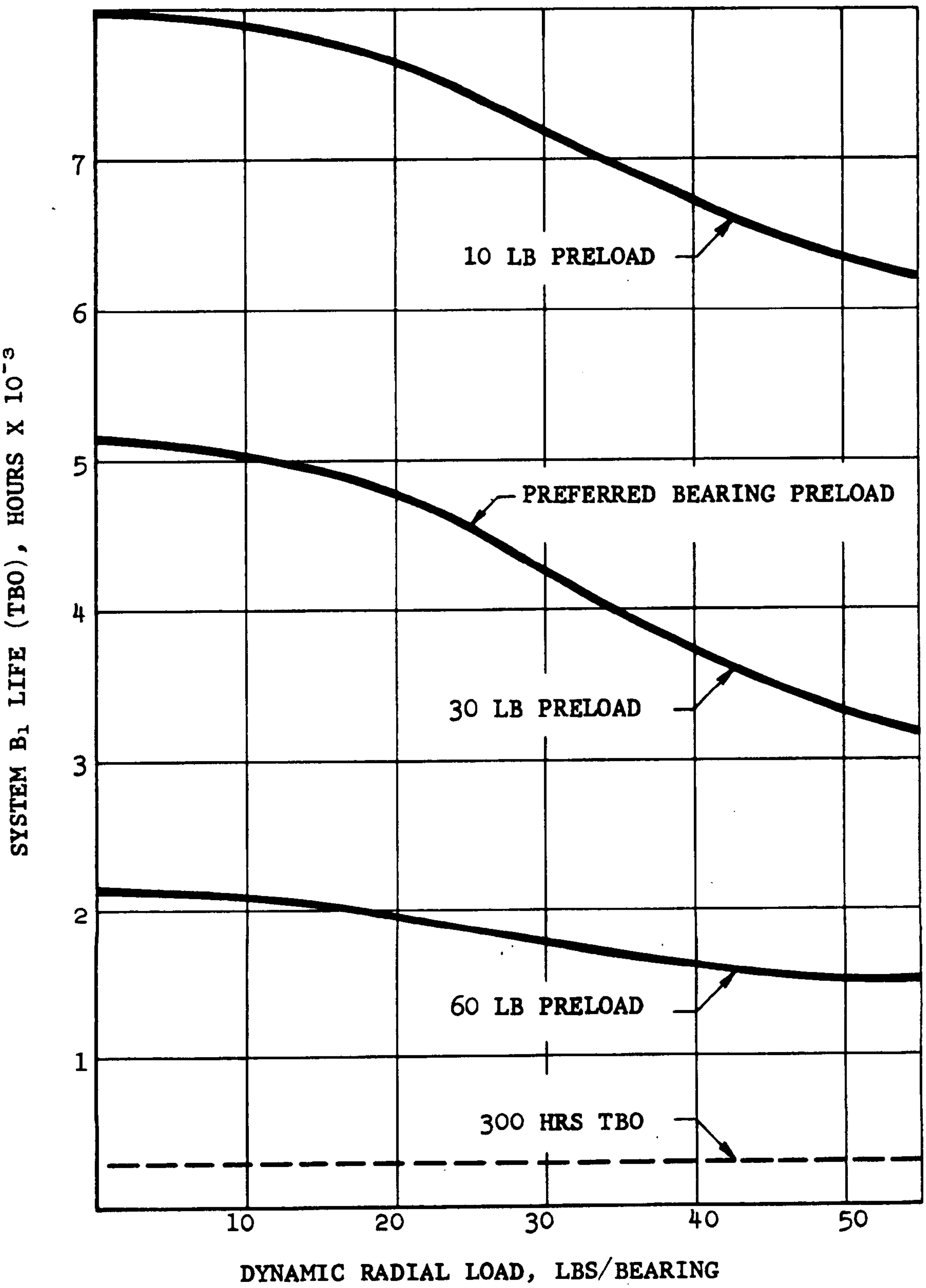
FIGURE 9

3.5 Bearing and Seal Design Data and Drawings

The angular-contact rolling-element bearing selected as a result of a digital computer program optimization for the research package should adequately meet the design objective of a time-between-overhaul (TBO) of 300 hours minimum when using air-oil mist lubrication (MIL-L-7808). The major characteristics of the chosen bearing (Part 358500) are:

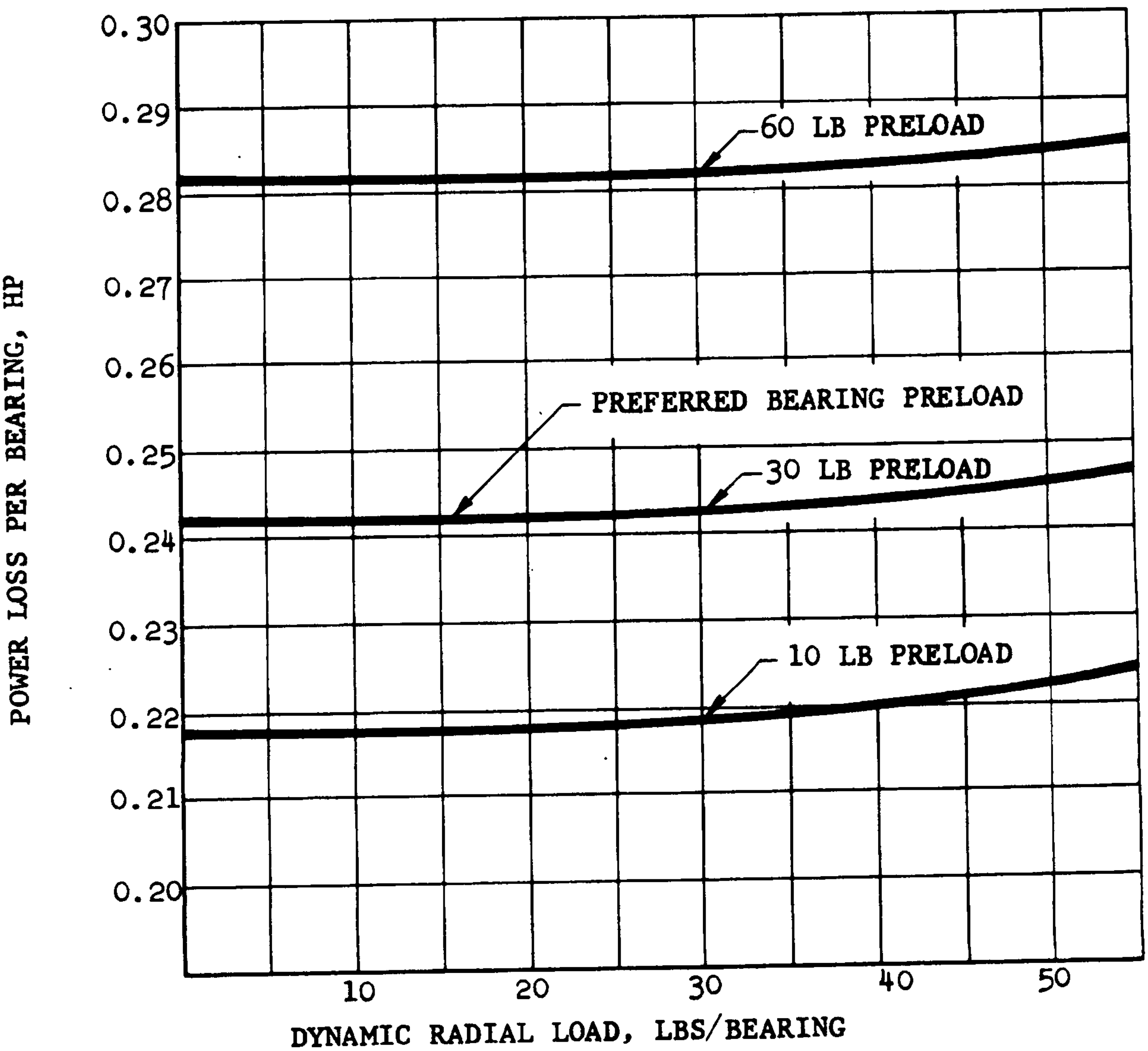
Bore diameter	20 mm
Outside diameter	42 mm
Width	12 mm
Number of balls	11
Ball diameter	9/32 inch
Inner-race curvature	52 to 53 percent of ball diameter
Outer-race curvature	52 to 53 percent of ball diameter
Contact angle	16 degrees
Ring and ball material	Consumable-Electrode vacuum-melted M-50 tool steel
Separator material	Iron-silicon-bronze, silver-plated

The unidirection (1 "g") radial bearing loads and thrust loads assumed for the analysis are shown in Table 3. The predicted bearing system life, B_1, for preloads of 10, 30, and 60 pounds for the compressor is shown in Figure 10. The predicted power loss per bearing for preloads of 10, 30, and 60 pounds for the compressor package is plotted in Figure 11. Representative package speeds, bearing loads, and predicted system B_1 life for the package is presented in Table 4. It is evident that the TBO design objective (300 hours minimum) can be easily met. The bearing configuration and material requirements are shown in Drawing 358500.



BEARING SYSTEM LIFE B_1
NASA BRU COMPRESSOR RESEARCH PACKAGE

FIGURE 10

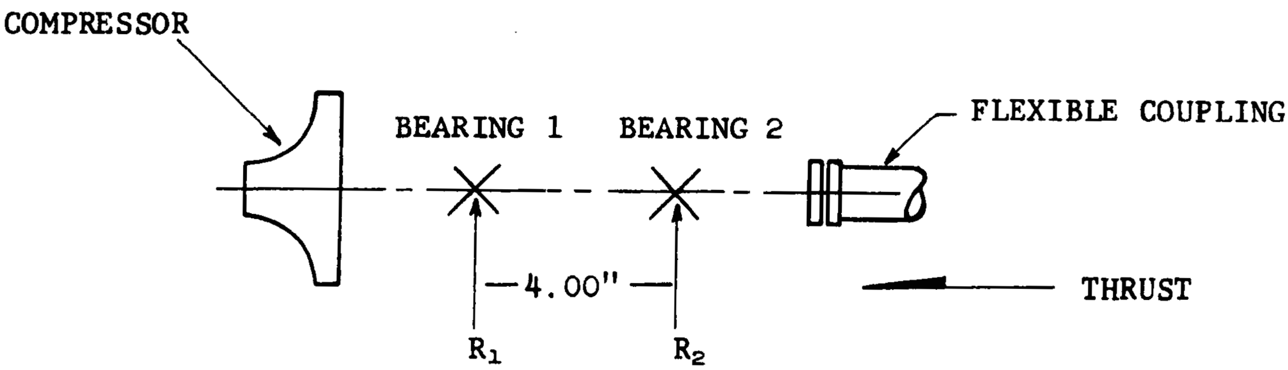


BEARING POWER LOSS FOR NASA BRU
COMPRESSOR RESEARCH PACKAGE BEARING

FIGURE 11

TABLE 3

UNIDIRECTIONAL BEARING LOADS ASSUMED FOR
BEARING ANALYSIS, COMPRESSOR
RESEARCH PACKAGE



NOTE: Bearing 2 takes thrust loads in the direction shown.

	R_1 (lbs)	R_2 (lbs)	Thrust (lbs)
Compressor Package	5.1	0.5	5

TABLE 4

COMPRESSOR RESEARCH PACKAGE
BEARING SYSTEM B_1 LIFE
(TBO)

Compressor (30 pounds being preload):

Speed (rpm)	Max. Bearing Load (lbs)	B_1 Life (Hours)
25,550	30	4,250
51,100	9	5,050
66,165	33	4,100

The carbon-face contact seal for the compressor is shown on Drawing 699683. Five vendors indicated their desire to participate in this program, three of whom were selected by the Contractor as being approved. The seal designs proposed by each of the three vendors were quite similar (standard O-ring configuration with wave washer spring loading). The internal configuration of the seal design allows for a constant pressure differential or direction of the pressure differential. The only face pressure incurred will result from the spring loading and O-ring drag. Thus, a very wide range of compressor wheel back-face pressures can be readily accommodated without seal carbon-face leakage or destruction.

3.6 Compressor Instrumentation

The compressor research package has a full compliment of static pressure instrumentation and provisions for the addition by the NASA, of total pressure and temperature instrumentation to assist in the aerodynamic performance evaluation of the compressor. The following is a list of the instrumentation and the provisions therefore as installed on the compressor research package:

(a) Inlet

(1) Three (3) static pressure taps in the same plane 120° apart. The bosses are machined with 1/8-inch pipe threads and a 0.030-inch diameter static pressure tap hole.

(2) Three (3) bosses for total pressure taps, 0.5-inch downstream of the static pressure taps and rotated 60° to the static taps and 120° apart. The bosses are machined with 1/8-inch threads.

(b) Rotor

(1) Three (3) sets of five static pressure taps along the rotor leading edge section of the rotor shroud set 120° apart.

(2) One (1) set of three (3) equally spaced machined bosses located axially at the rotor tip for blade clearance probes.

(c) Diffuser

(1) Vaneless section - Three (3) static pressure taps equally spaced on the rotor shroud located between rotor outlet and vaned diffuser inlet.

(2) Vaned section - Two (2) sets of five (5) static pressure taps each along the diffuser mid-channel streamline, one (1) set on each side of a diffuser passage.

(d) Scroll exit

(1) Four (4) static pressure taps in the same plane, 90° apart. The bosses are machined with 1/8-inch pipe threads and a 0.030-inch diameter static pressure tap hole.

(2) Four (4) bosses for total pressure taps, 0.5-inch downstream of the static taps, rotated 45° to the static taps and 90° apart. The bosses are machined with 1/8-inch pipe threads.

e. Bearings

(1) Three (3) C.A. thermocouples on each bearing

f. Shaft speed

(1) Three (3) Electro Products (No. 3016) shaft speed pickups spaced 45° apart.

4.0 GENERAL UNIT DESCRIPTION

The dimensional outline of the compressor research package is shown in Drawing 699680. This drawing also defines the interfaces between (a) the end of the impeller shaft machined to mate with the drive coupling, Drawing 699667 (NASA Drawing CC844330), (b) the bolt flanges at the compressor inlet and discharge to permit attachment to adaptor flanges, Drawings 699767 and 699768 and (c) the mating electrical connectors (temperature, speed and power) and pipe fittings. General operating conditions for the unit are also specified.

A cross-sectional view of the compressor research package is shown in Assembly Drawing (699681). The unit consists of the impeller assembly (Item 8) mounted in the main housing (Item 1) on two antifriction bearings (Item 6, also Drawing 358500). Both bearings are resiliently mounted with a spring rate of 30,000 pounds per inch using the bearing mount assembly (Item 5). This spring rate was chosen so that the operating speed range would be between a low second critical and a very high third critical; a coil spring (Item 30) provides 30 pounds of axial preload on the bearings. An oil jet (Item 27) supplies pressurized, air-oil mist to each bearing.

Labyrinth type seals are provided at each end of the housing. The impeller end seal has a purge chamber located in the middle of the seal. The impeller end is also equipped with a carbon-face type oil seal (Item 9, also Drawing 699683).

The compressor scroll (Items 24, 25, and 26) is attached to the main housing by a bolted flange. Shimming to obtain the desired compressor-wheel-shroud-face clearance is accomplished at this flange by providing a shim of predetermined thickness between the housing and the scroll flange. A design value of the clearance was established at 0.007-0.009 inch. Sealing at this shim is accomplished with the O-rings (NAS 1593-174). A rigid mounting base (Item 2) provides for mounting the compressor research package on a test stand bed-plate.

5.0 COMPRESSOR RESEARCH PACKAGE ACCEPTANCE TESTING

The compressor research package acceptance test was performed at the AiResearch Manufacturing Company, Phoenix, Arizona on August 15, 1967. All testing was conducted at the Phoenix Division laboratory facility and was witnessed by a representative of the NASA.

The acceptance test setup consisted of three basic components mounted on an aluminum fixture (see Figures 12, 13, and 14) as follows:

(a) AiResearch Constant Speed Drive Starter (CSDS) turbine

(b) Coupling (NASA Drawing CC844330)

(c) Compressor Research Package

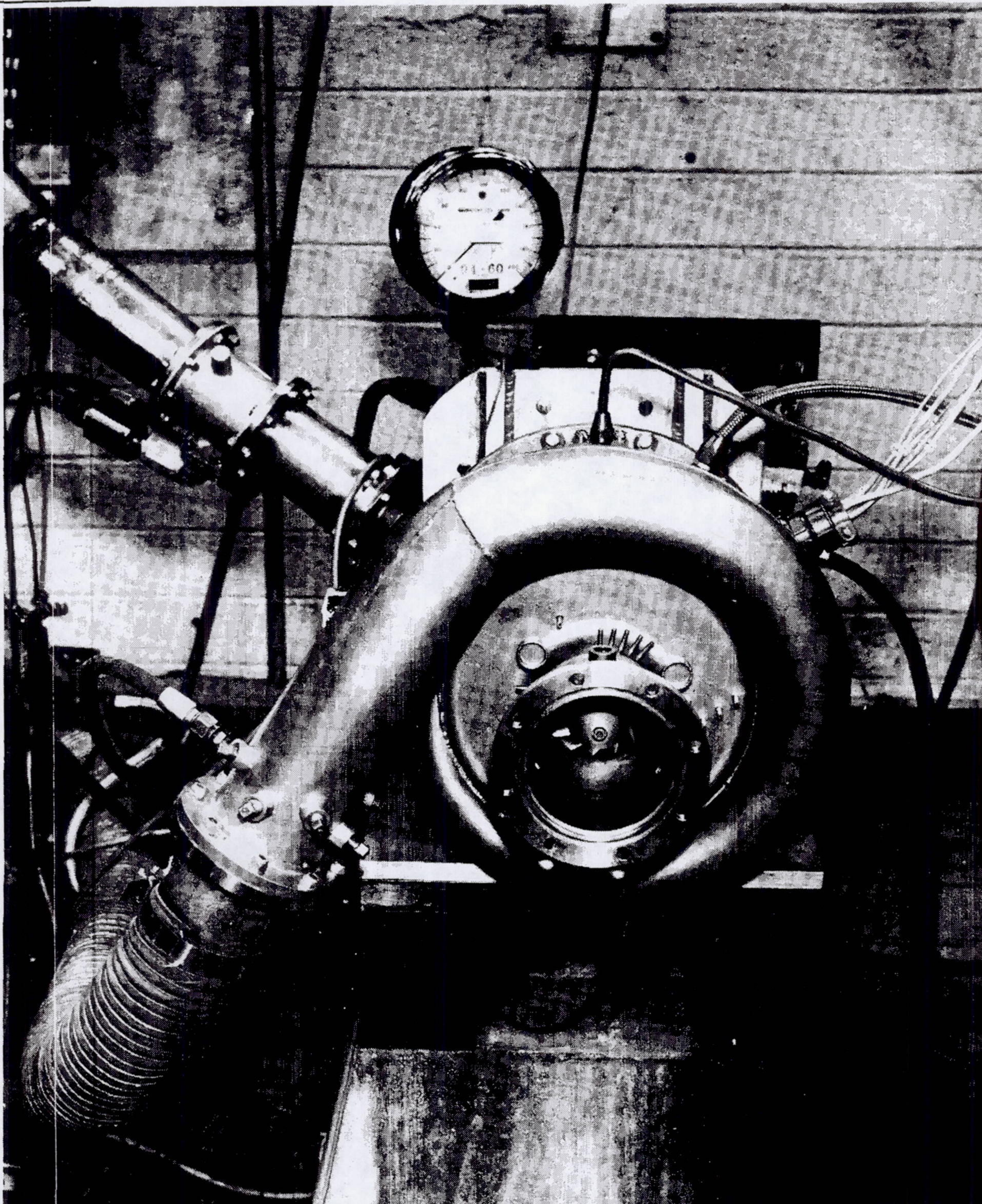
During the test the CSDS turbine, supplied with plant compressed air energy, was used to drive the compressor package through the 699667 coupling. Air-oil mist lubrication for the package was furnished by a calibrated Norgren oiler.

The acceptance test was conducted as follows: A critical speed of the system to 51,200 rpm (100 percent design speed). The system was then stabilized at design speed for the required 30 minutes, during which time unit speed, vibration, and bearing temperatures were manually recorded at five minute intervals.

Following this 30 minute cycle, the speed was increased to 61,400 rpm (120 percent design speed) for 10 minutes. The

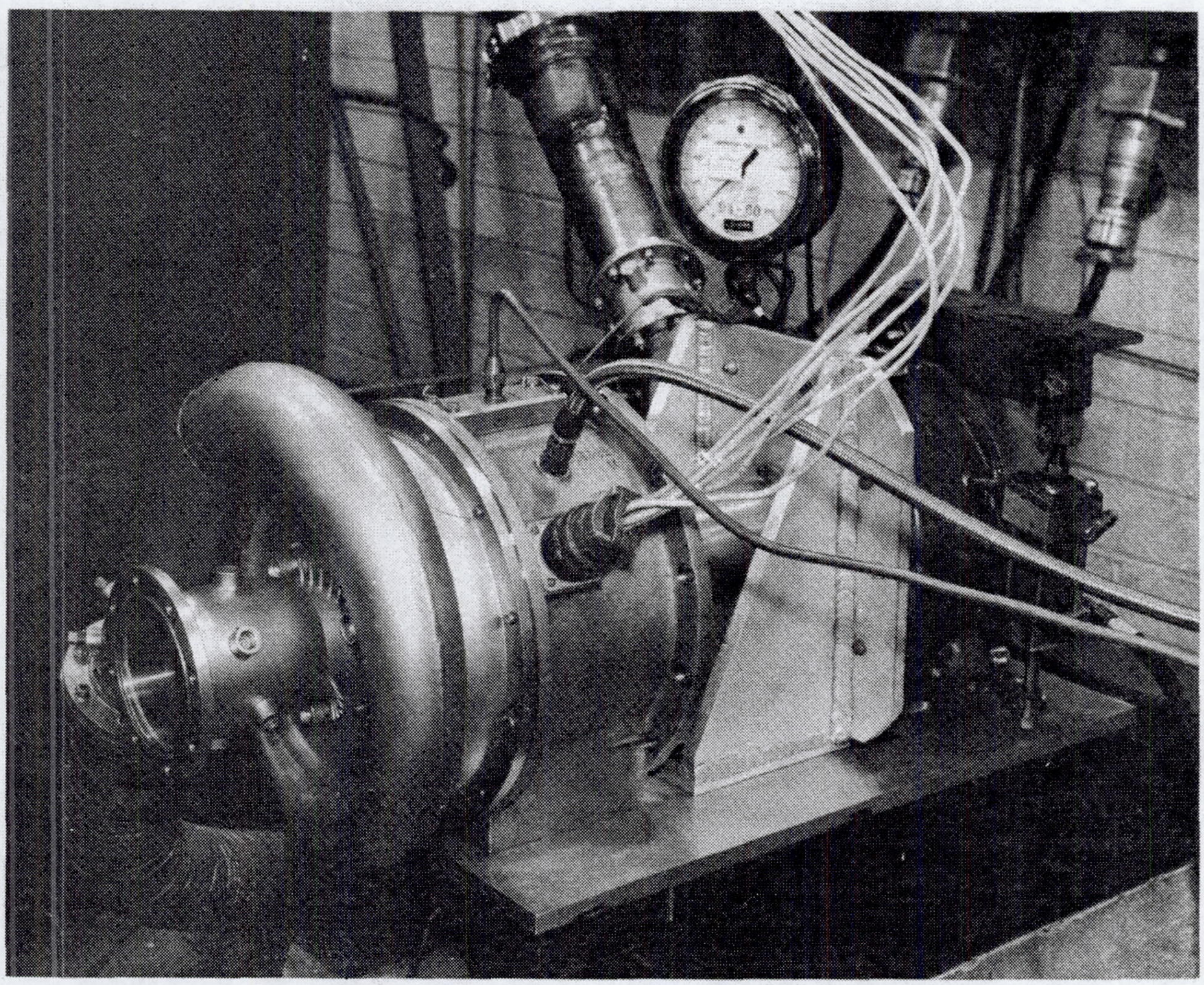
acceptance test was then complete and the system was shut down.

Acceptance test data, including assembly instructions, parts list, delivery spares and the unit build history have been delivered to the NASA Lewis Research Center in a separate document in accordance with contract requirements.



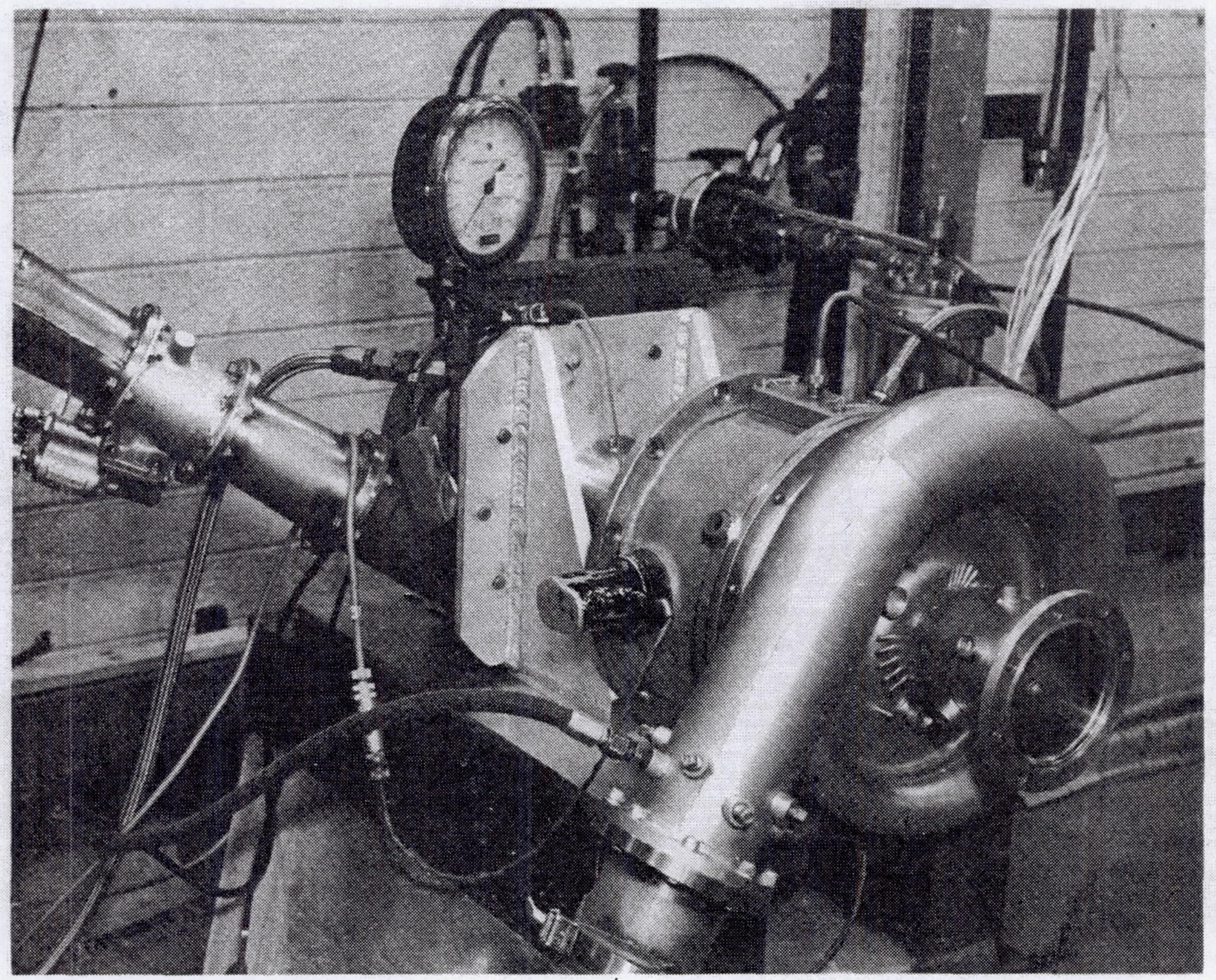
COMPRESSOR RESEARCH PACKAGE MOUNTED
IN ACCEPTANCE TEST RIG-FRONT VIEW

FIGURE 12



COMPRESSOR RESEARCH PACKAGE MOUNTED IN ACCEPTANCE TEST RIG - LEFT SIDE VIEW

FIGURE 13



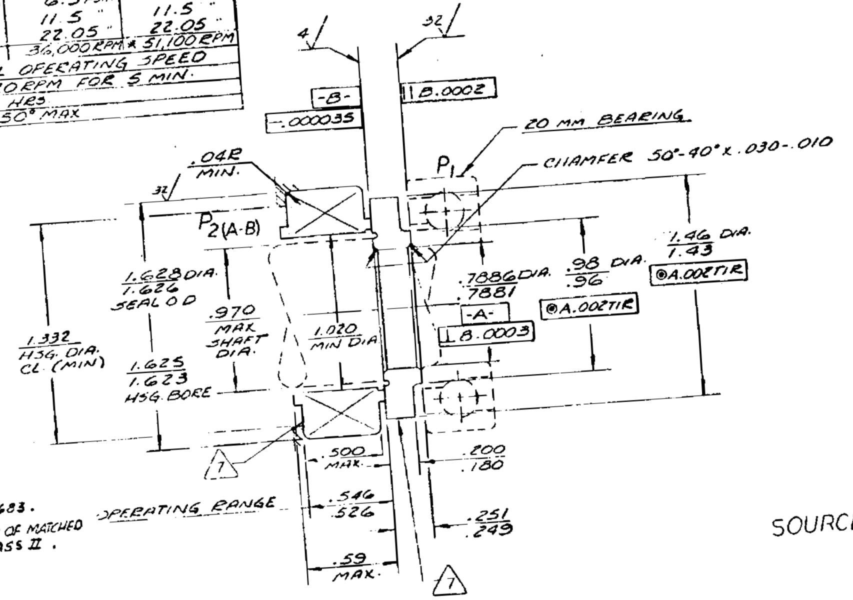
COMPRESSOR RESEARCH PACKAGE MOUNTED IN
ACCEPTANCE TEST RIG - RIGHT SIDE VIEW

FIGURE 14

PART NO.
699683-1

OPERATING CONDITIONS

	P_1	$P_{2\text{-}A}$	$P_{2\text{-}B}$
MEDIUM	AIR-OIL MIST (MIL-L-7808)	HELIUM-XENON	ARGON
	14.7 PSIA	6.5 PSIA	6.5 PSIA
	14.7 "	11.5 "	11.5 "
	14.7 "	22.05 "	22.05 "
SPEED		36,000 RPM	* 51,100 RPM
* NOTE: NORMAL OPERATING SPEED 61,320 RPM FOR 5 MIN.			
OVERSPEED	61,320 RPM FOR 5 MIN.		
LIFE	300 HRS		
TEMPERATURE	350° MAX		



SOURCE CONTROL DRAWING

11. THESE PARTS TO BE MANUFACTURED, INSPECTED, STOCKED AND SOLD AS REPLACEMENT PARTS IN MATCHED SETS ONLY.
10. SHAFT MATERIAL: 4340
9. SEAL HOUSING MATERIAL: 300 SERIES STAINLESS
8. PROCUREMENT SOURCE(S) PER ASL 699683.
7. AIRESEARCH PART NUMBER & SERIAL NUMBER OF MATCHED SET HERE PER AIRESEARCH SPEC. 5014, CLASS II.
6. ALL DESIGN AND PART NUMBER CHANGES REQUIRE PRIOR AIRESEARCH APPROVAL.
5. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDOR(S) LISTED HEREON IS APPROVED BY AIRESEARCH MANUFACTURING COMPANY, PHOENIX, ARIZONA FOR USE IN THE APPLICATION(S) SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY AIRESEARCH MANUFACTURING COMPANY OR BY THE GOVERNMENT PROCURING ACTIVITY.
4. DRAWING REVISIONS FOR SUBSTITUTE ITEMS SHALL NOT BE MADE WITHOUT PRIOR APPROVAL BY AIRESEARCH MANUFACTURING COMPANY.
3. IDENTIFY PACKAGING WITH AIRESEARCH PART NUMBER.
2. PARTS PROCURED BY VENDOR PART NUMBER SHALL BE PROCURED IN ACCORDANCE WITH THIS AIRESEARCH SOURCE CONTROL DRAWING.
1. DETAILS OF DESIGN AND CONSTRUCTION OTHER THAN SHOWN SHALL BE AT OPTION OF VENDOR.

* See tab block (upper left corner) for PART NUMBER

CRITICAL ITEM

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-5535, STANDARD DRAWING INTERPRETATIONS.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED

QUANTITY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION	ZONE

LIST OF MATERIAL

-1	699671-1	699670-1
REQD	NEXT ASSY	USED ON
HEAT TREATMENT		PROCESS
HARDNESS AND SPEC		NAME AND SPEC

SIGNATURES	DATES
DFT	
CHK	1-11-67
MFG	
MATL	
STRESS	
AERO	
APPD	1-13-67
APPD	
DESIGN ACTIVITY APPD	1-16-67
OTHER ACTIVITY APPD	

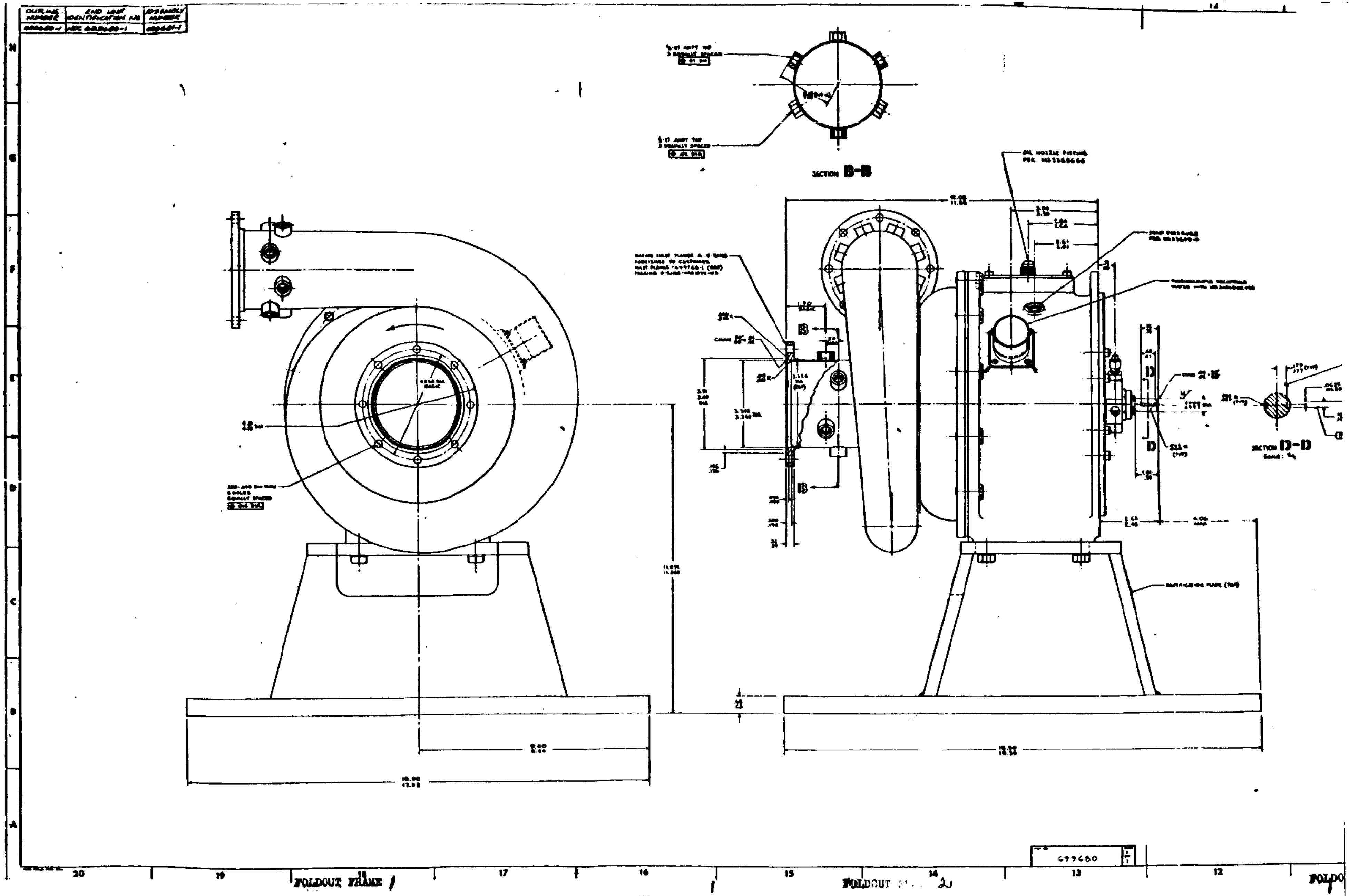
AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

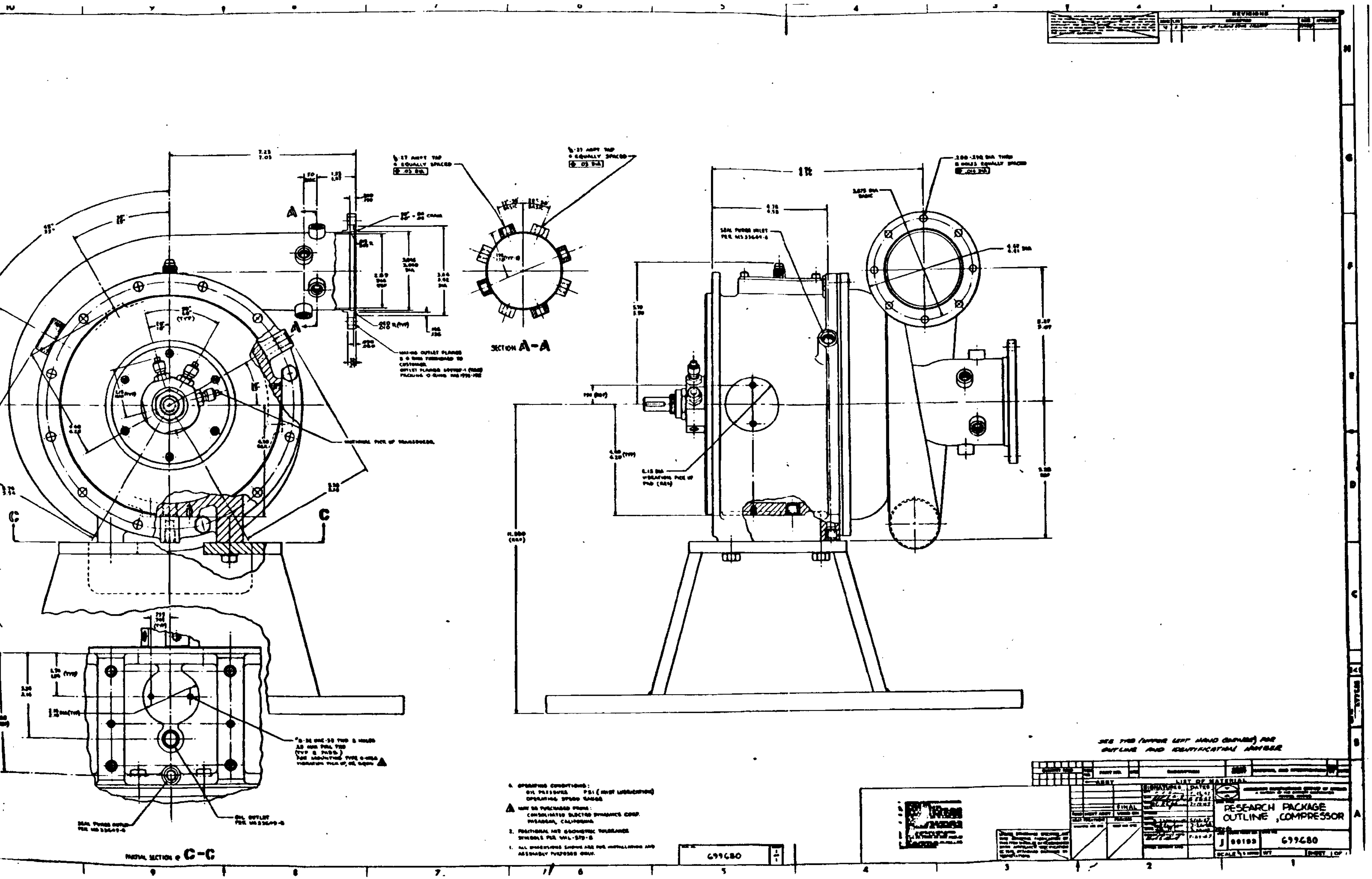
DWG TITLE: SEAL & ROTOR SET, MATCHED

SIZE	CODE IDENT NO.	DWG NO.
C	99193	699683
SCALE 2X	WT	SHEET 1 OF 1

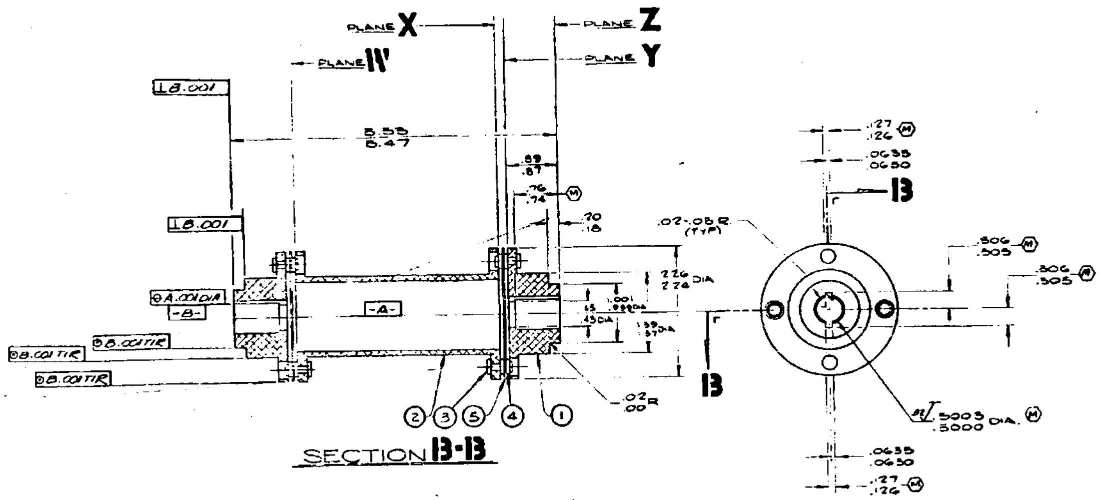
FOLDOUT FRAME 2

699683


SECTION B-B
SECTION D-D
OIL NOZZLE FITTING
699680
FOLDOUT FRAME


SECTION A-A
PARTIAL SECTION C-C
LIST OF MATERIAL
FINAL
RESEARCH PACKAGE
OUTLINE ,COMPRESSOR
J
699680
SCALE
SHEET 1 OF 1

PART NO
699667-1



13. POSIONAL AND GEOMETRIC TOLERANCE SYMBOLS PER MIL-STD-8.

12. (C) DESIGNATES CRITICAL CHARACTERISTIC
(M) DESIGNATES MAJOR CHARACTERISTIC

(M) 11. DYNAMIC BALANCE REQUIREMENTS:

11.1 BALANCING SPEED 2500 RPM MIN

11.2 A SINGLE ARBOR PRE-BALANCED TO WITHIN .0002 OZ-IN AND HAVING DATUM B LOCATING DIAS CONCENTRIC TO ITS ROTATING AXIS WITHIN .0001 TIR SHALL BE UTILIZED THROUGHOUT BALANCING PROCEDURE.

11.3 DYNAMICALLY BALANCE ITEMS INDIVIDUALLY IN PLANES Z&Y TO WITHIN .0002 OZ-IN. REMOVE METAL FROM PLANES Z&Y IF NECESSARY.

11.4 COMPLETELY ASSEMBLY COUPLING & DYNAMICALLY BALANCE ASSEMBLY ABOUT PLANES W&X TO WITHIN .0005 OZ-IN. REMOVE METAL FROM PLANES W&X IF NECESSARY.

10. NO SET SCREWS, ACCESS HOLES OR ANODIZE.
9. FINISH ALL OVER EXCEPT NOTED.
8. DETAILS OF DESIGN AND CONSTRUCTION OTHER THAN SHOWN TO BE AT OPTION OF VENDOR.
7. PARTS PROCURED BY VENDOR PART NUMBER SHALL BE PROCURED IN ACCORDANCE WITH THIS AIRESEARCH SOURCE CONTROL DRAWING.
6. IDENTIFY PACKAGING WITH AIRESEARCH PART NUMBER.
5. DRAWING REVISIONS FOR SUBSTITUTE ITEMS SHALL NOT BE MADE WITHOUT PRIOR AIRESEARCH APPROVAL.
4. ONLY THE ITEM DESCRIBED ON THIS DRAWING WHEN PROCURED FROM THE VENDORS LISTED HEREON IS APPROVED BY AIRESEARCH MANUFACTURING CO OF PHOENIX, ARIZONA FOR USE IN THE APPLICATIONS SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY AIRESEARCH MFG. CO. OR BY THE GOVERNMENT PROCURING ACTIVITY.
3. ALL DESIGN AND PART NUMBER CHANGES REQUIRE PRIOR AIRESEARCH APPROVAL.
2. APPLY AIRESEARCH PART NUMBER PER AIRESEARCH SPEC. MC5014 CL V A.
1. PROCUREMENT SOURCES PER ASL 699667.

NOTES:

CRITICAL ITEM

SEE TAB. BLOCK (UPPER LEFT CORNER) FOR PART NUMBER.

SOURCE CONTROL DRAWING

QUANTITY REQD	ITEM NO	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
2	5	-19		DISC		BERYLLIUM COPPER
16	4	-17		WASHER		BRASS QQ-B-626
8	3	-15		RIVET		BRASS QQ-B-626
1	2	-13		CENTER MEMBER		AL ALLOY AMS 4122/7075-T
2	1	699667-11		FLANGE		AL ALLOY AMS 4122/7075-T
←ASSY						LIST OF MATERIAL

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-5535, STANDARD DRAWING INTERPRETATIONS.

AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

COUPLING ASSEMBLY DRIVE

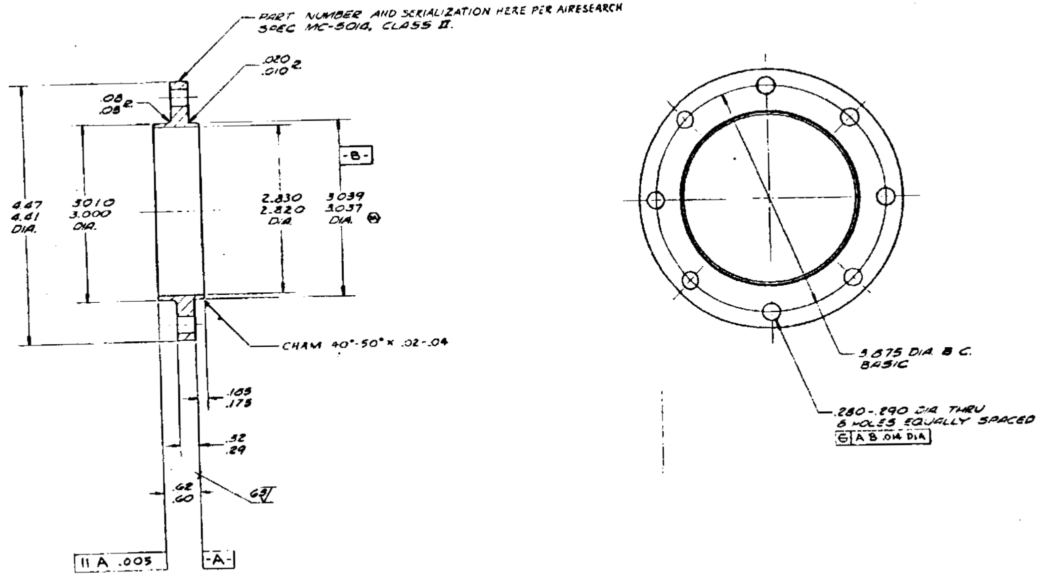
SIZE	CODE IDENT NO	DWG NO
D	99193	699667

SCALE 1/1 | WT – | SHEET

FOLDOUT FRAME 1

FOLDOUT FRAME 2

PART NUMBER
699767-1



4. FLUORESCENT INSPECT PER AMS 2645
3. Ⓜ Designate Major Characteristics
2. SERIAL NUMBER CONTROL MUST BE MAINTAINED ON THIS PART THROUGHOUT MANUFACTURING AND ASSEMBLY CYCLES AND AFTER FINISH MACHINING. SERIAL NUMBERS SHALL BE APPLIED BY THE METHOD AND AT THE LOCATION SPECIFIED.
1. FINISH ALL OVER 125 OR AS NOTED.

CRITICAL ITEM

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-5535, STANDARD DRAWING INTERPRETATIONS.

SEE TAB. BLOCK (UPPER LEFT CORNER) FOR PART NUMBER.

QUANTITY REQD	ITEM NO.	PART NO.	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
						347 CRES AMS5646

LIST OF MATERIAL

FINAL	699767-1
REQD NEXT ASSY	USED ON
HEAT TREATMENT	PROCESS
HARDNESS AND SPEC	NAME AND SPEC
	NOTED

SIGNATURES	DATES
DR	6-8-67
CHK	4-14-67
	4-14-67
MATL	4-14-67
STRESS	4-18-67
PROJ	
ANG A.J. Weitzman	4-17-67
MFG	4-14-67
	4-17-67
OTHER ACTIVITY APPR	

AIRESEARCH MANUFACTURING COMPANY OF A DIVISION OF THE GARRETT CORPORATION PHOENIX ARIZONA

DWG TITLE FLANGE, COMPRESSOR OUTLE

SIZE	CODE IDENT NO	DWG NO.
D	99193	69976
SCALE 1/1	WT	SHEET

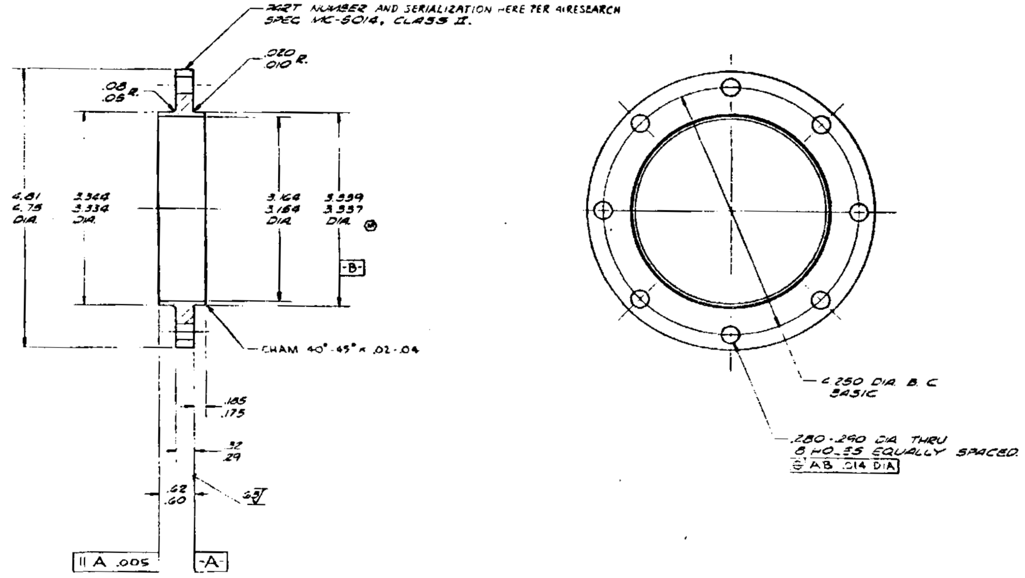
REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

FOLDOUT FRAME 2

FOLDOUT FRAME 1

PART NUMBER
699768-1



4. FLUORESCENT PENETRANT INSPECT PER AMS 2645
3. ® Designate Major Characteristics
2. SERIAL NUMBER CONTROL MUST BE MAINTAINED ON THIS PART THROUGHOUT MANUFACTURING AND ASSEMBLY CYCLES AND AFTER FINISH MACHINING. SERIAL NUMBERS SHALL BE APPLIED BY THE METHOD AND AT THE LOCATION SPECIFIED.
1. FINISH ALL OVER 125 OR AS NOTED.

SEE TAB. BLOCK (UPPER LEFT CORNER) FOR PART NUMBER.

CRITICAL ITEM

UNLESS OTHERWISE SPECIFIED ON THIS DRAWING, FABRICATION OF THIS ITEM SHALL BE IN ACCORDANCE WITH AIRESEARCH SPECIFICATION SC-3535, STANDARD DRAWING INTERPRETATIONS.

QUANTITY REQD	ITEM NO.	PART NO	SYM	DESCRIPTION	CODE IDENT	MATERIAL AND SPECIFICATION
						347 CRES AMS5646 or 55
←ASSY						

LIST OF MATERIAL

		SIGNATURES	DATES
1-1 FINAL	699768-1	DFT	2-2-67
REQD NEXT ASSY	USED ON	CHK	4-14-67
HEAT TREATMENT	PROCESS	MATL	4-14-67
MATINFS AND SPEC	NAME AND SPEC	STRESS	4-14-67
	NOTED	APPD	4-17-67
		DESIGN	4-17-67
		OTHER ACTIVITY APPD	

AIRESEARCH MANUFACTURING COMPANY OF A DIVISION OF THE GARRETT CORPORATION PHOENIX, ARIZONA

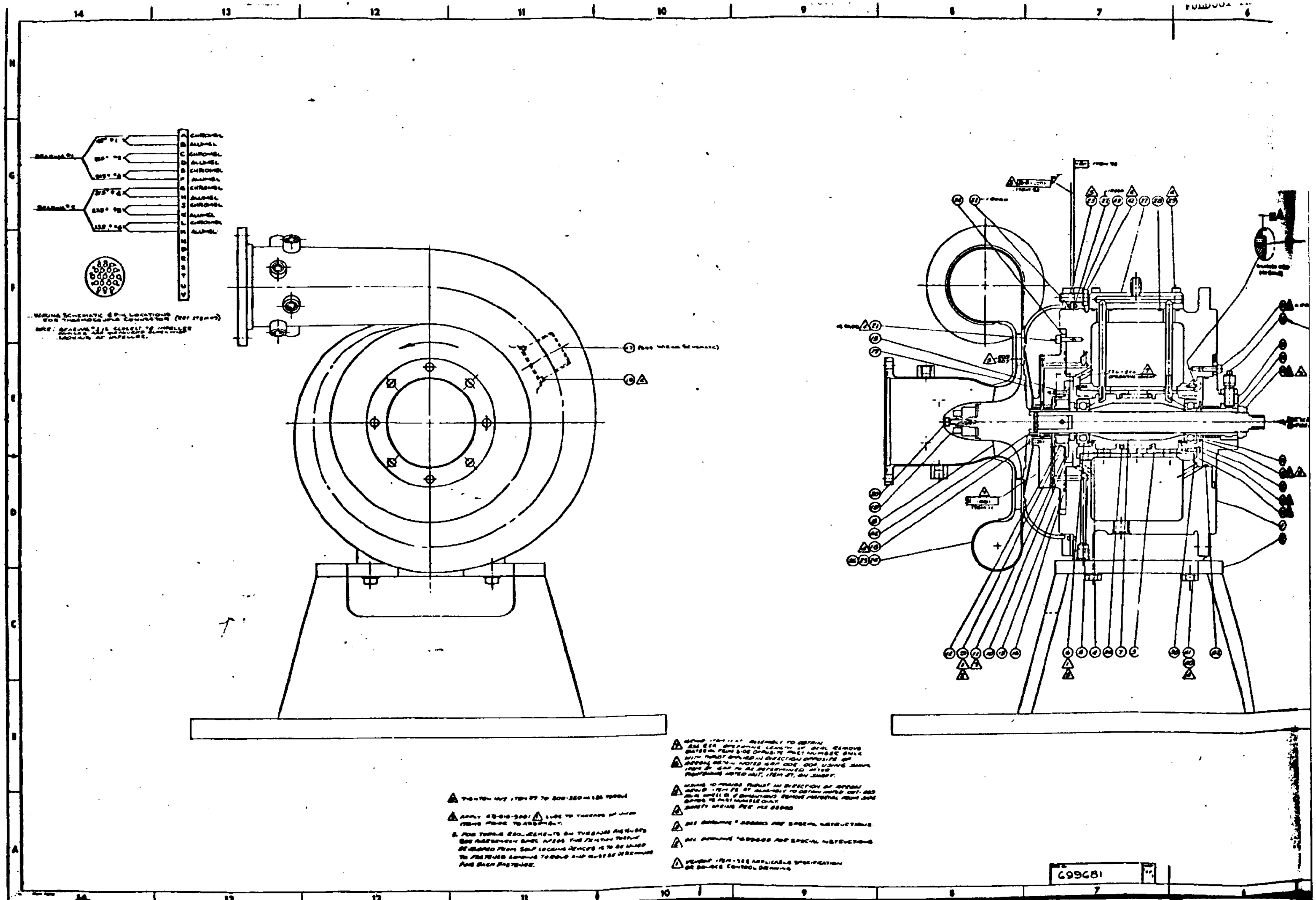
DWG TITLE: FLANGE, COMPRESSOR INLET

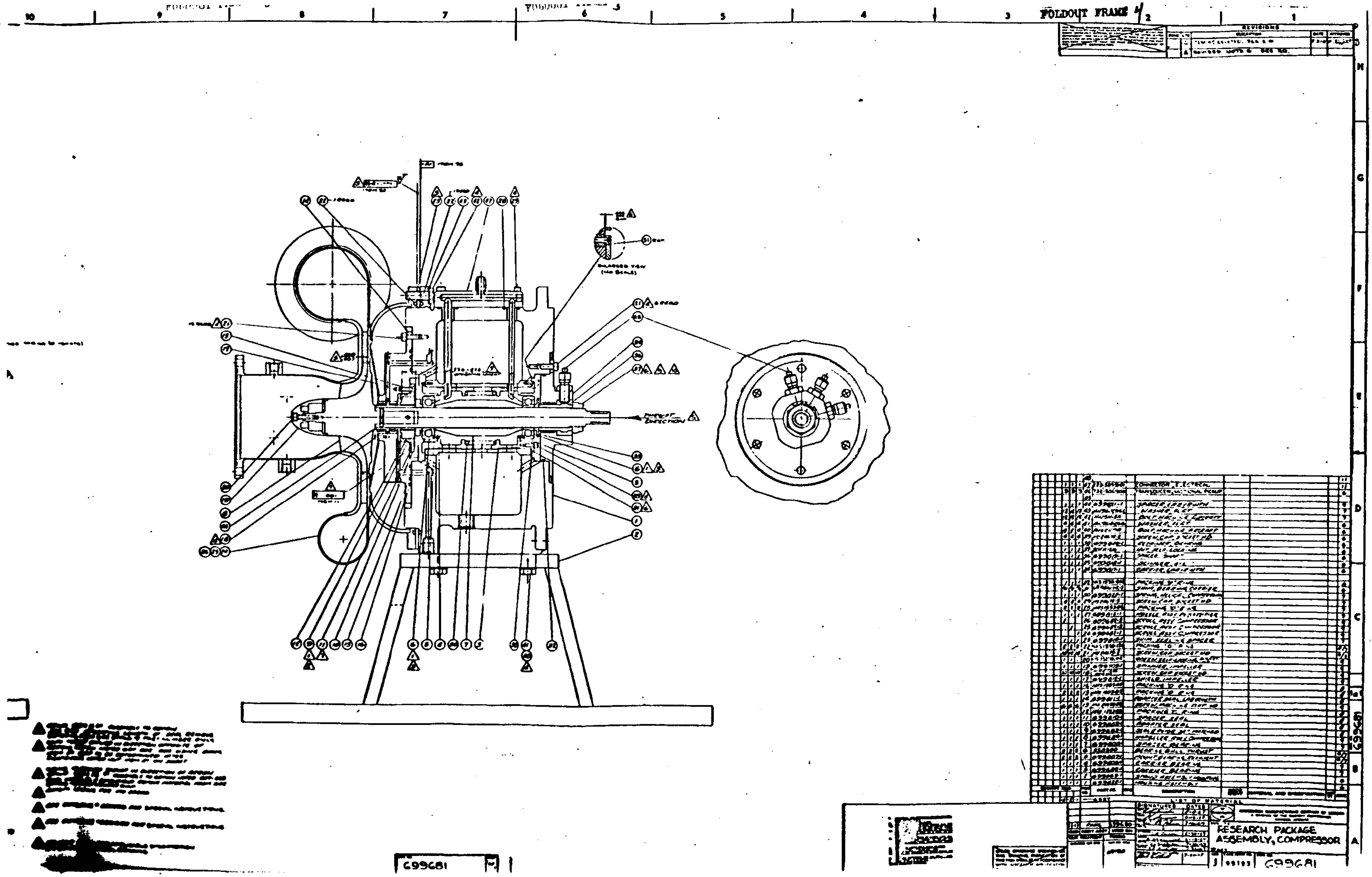
SIZE D | CODE IDENT NO. 99193 | DWG NO. 69976

SCALE 1/1 | WT | SHEET

FOLDOUT FRAME 1

FOLDOUT FRAME 2


C99681
WIRING SCHEMATIC & PIN LOCATIONS FOR THERMOCOUPLE CONNECTOR
CHROMEL
ALUMEL

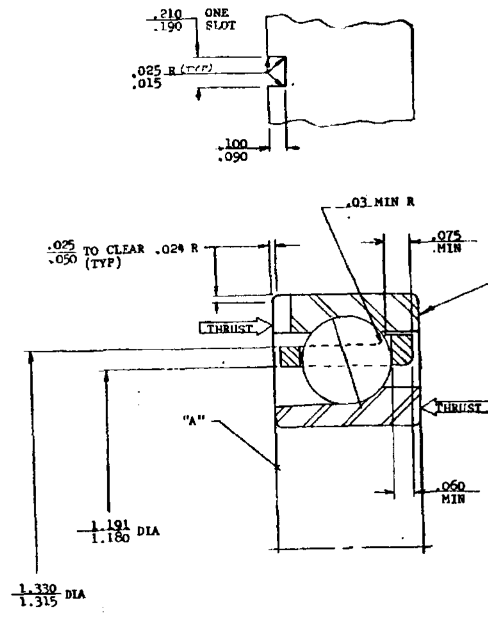


FOLDOUT FRAME 2
REVISIONS
LIST OF MATERIAL
RESEARCH PACKAGE
ASSEMBLY, COMPRESSOR
C99681
C99681

PART NUMBER
358500-1

REVISIONS

LTR	DESCRIPTION	DATE	APPR
A	ADDED LEADER & ARROWHEAD	6-5-67	[illegible]
B	... DRN # 18140, SPEC. NOTE WAS: MARK PART NUMBER AND SERIAL NUMBER HERE PER AIRESEARCH SPEC. MC-5014 CLASS II	11/7/67	[illegible]
C	REVISED SPEC. NOTE WAS: MARK PART NUMBER AND SERIAL NUMBER HERE PER AIRESEARCH SPEC. MC-5014, CLASS II. MARKING ON O.D. OPTIONAL. SEE E.O.	11/10/67	[illegible]
D	ADDED .025/.015 R (TYP) — SEE E.O.	7/31/68	[illegible]



—MARK PART NUMBER AND SERIAL NUMBER HERE PER AIRESEARCH SPEC MC-5014, CLASS II OR III C
MARKING ON O.D. OPTIONAL

See tab block (upper left corner) for PART NUMBER

BEARING DESCRIPTION: BALL, ANGULAR CONTACT, 7104		GRADE: AIRESEARCH 5
INNER RING	OUTER RING	ASSEMBLED BEARING CHARACTERISTICS
MATERIAL: CEVM M-50 PER AMS 6490 Rc 60 MIN	MATERIAL: CEVM M-50 PER AMS 6490 Rc 60 MIN	TOTAL DIAMETRAL (M) CLEARANCE
BORE: .7874-.7872 (20 MM) (M) TAPER/FT:	OD: 1.6535-1.6533 (42 MM) (M)	.0013-.0017 UNDER 1 LBS GAGE
WIDTH: .4724-.4624 (12 MM) (M)	FLANGE OD:	SPECIAL FEATURES
RACE DEPTH: 20 MIN % BALL DIA	WIDTH: .4724-.4674 (12 MM)	1. FACES "A" TO BE FLUSH WITHIN ±.0001 WITH 5 LBS THRUST LOAD APPLIED IN DIRECTION SHOWN.
RACE CURVATURE: 52-53 % BALL DIA	FLANGE WIDTH:	2. PARTS SHALL NOT CHANGE IN DIMENSION IN EXCESS OF .000050 IN/IN AFTER EXPOSURE TO 750°F FOR 10 HOURS.
SEPARATOR PILOT LAND TO GROOVE RUNOUT: TIR	RACE DEPTH: 18 MIN % BALL DIA	
SEPARATOR	RACE CURVATURE: 52-53 % BALL DIA	3. SEPARATOR TO BE SILVER PLATED .0005-.002 THICK PER AMS 24..
MATERIALS: SILICON IRON BRONZE PER AMS 4616	SEPARATOR PILOT LAND TO GROOVE RUNOUT: .0005 TIR	4. CONTACT ANGLE 19° (REF).
CONSTRUCTION: MACHINED	ROLLING ELEMENTS	5. SEPARATOR BALL POCKET SURFACE CIRCUMFERENTIALLY FORE AND AFT TO BE AT BEARING PITCH DIAM..
ASSEMBLY: ONE-PIECE	MATERIAL: CEVM M-50 PER AMS 6490 Rc 60 MIN	6. HEAT TREATMENT OF CEVM M-50 PER SPEC H-55.
PILOTING SURFACE: OUTER RING LAND	COMPLEMENT PER ROW: 11-9/32 DIA	7. BEARING TO BE NON-SEPARABLE UNDER NORMAL HANDLING.
PILOT CLEARANCE: .006-.012	CLOSURES	
OPERATIONAL LUBRICANT	NUMBER: NONE	
NAME: OIL, SYNTHETIC, AIRCRAFT GAS TURBINE, LUBRICATING	TYPE:	
MILITARY SPEC NO.: MIL-L-7808	MATERIAL:	
BEARING PRELUBRICATION: DIP AND DRAIN	CONSTRUCTION:	

PACKAGING PER AIR. SPEC CP-14	PRODUCTION BULK PACK	COMMERCIAL SPARES PACK	MILITARY SPARES PACK
PRESERVATIVE:	MIL-L-6085	MIL-L-6085	MIL-P-197
AIRESEARCH PART NUMBER:	358500 -1	358500 -1	358500 -4
PROCUREMENT PER ASL: 358500			

9. (C) DESIGNATES CRITICAL CHARACTERISTIC
(M) DESIGNATES MAJOR CHARACTERISTIC
8. PARTS SHALL CONFORM TO AIRESEARCH SPEC. SC-5354
7. PARTS PROCURED BY VENDOR PART NUMBER SHALL BE PROCURED IN ACCORDANCE WITH THIS AIRESEARCH SOURCE CONTROL DRAWING.
6. IDENTIFY PACKAGING WITH AIRESEARCH PART NUMBER.
5. ALL DESIGN AND PART NUMBER CHANGES SHALL RECEIVE PRIOR AIRESEARCH APPROVAL.
4. ONLY THE ITEMS LISTED ON THE ASL AND IDENTIFIED BY VENDOR'S NAMES, ADDRESSES AND PART NUMBERS HAVE BEEN TESTED AND APPROVED FOR USE IN THE END UNIT. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR TESTING AND APPROVAL BY AIRESEARCH.
3. MILITARY SPARES PACK BEARINGS ARE INTENDED TO FILL MILITARY SPARES ORDERS. BEFORE INSTALLATION, WASH OUT THE PRESERVATIVE AND REPLACE WITH OPERATING LUBRICANT. AFTER THIS OPERATION THE -4 IDENTIFICATION IS CHANGED TO -1 AND THE BEARINGS BECOME INTERCHANGEABLE WITH THE PRODUCTION BULK AND COMMERCIAL SPARES PACK BEARINGS. THEY SHOULD NOT BE USED IN FACTORY INSTALLATIONS BECAUSE OF THEIR RELATIVELY HIGH COST.
2. FOR ECONOMY, PRODUCTION BULK PACK BEARINGS ARE PREFERRED FOR ALL FACTORY INSTALLATIONS. COMMERCIAL SPARES PACK BEARINGS ARE INTENDED TO FILL COMMERCIAL SPARES ORDERS.
1. PRODUCTION BULK AND COMMERCIAL SPARES PACK BEARINGS ARE INTERCHANGEABLE.
UNLESS OTHERWISE SPECIFIED:

CRITICAL ITEM
SATISFACTORY PERFORMANCE OF THE ... PRODUCT DEPENDS ON THE INTEGRITY AND RELIABILITY OF THIS SELECTED CRITICAL ITEM. THE GARRETT CORPORATION RECOMMENDS PROCUREMENT FROM THE ORIGINAL SUPPLIER AS SET FORTH IN ASPE 1.312

SOURCE CONTROL DRAWING	
SIGNATURES	DATES
DFT [signature]	4-5-67
CHK [signature]	1-..-67
APPD [signature]	11/1/67
APPD	
APPD [signature]	2-16-67
DESIGN ACTIVITY APPD [signature]	2-16-67
OTHER ACTIVITY APPD	

AIRESEARCH MANUFACTURING COMPANY
A DIVISION OF THE GARRETT CORPORATION
PHOENIX, ARIZONA

DWG TITLE: BEARING, BALL, THRUST

SIZE	CODE IDENT NO.	DWG NO.
C	99193	358500
SCALE NONE	WT –	SHEET OF

FOLDOUT FRAME 1

FOLDOUT FRAME 2

N6922173

BF

BIN:	M2	10-14-03
INVOICE:	1286013	
SHIPTO:	1*85776	
PAYMENT:	NONE	